FINAL REPORT

VOLUME 3

NORMAL PROCESSING ANALYSIS

LAUNCH SITE PROCESSING OF HAZARDOUS PAYLOADS

MAY 1975

Contract NAS10-8676

APPROVED BY

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FOREWORD

This document constitutes Volume 3 of a seven-volume Final Report, prepared by Teledyne Brown Engineering, Huntsville, Alabama, under NASA Contract No. NAS10-8676, Launch Site Processing of Hazardous Payloads. This study required a thorough analysis of the impact on the launch site and its operations by hazardous Space Shuttle payloads.

The seven volumes of the Final Report are as follows:

Volume 1. EXECUTIVE SUMMARY: This volume presents a concise review of the results of the study tasks and summarizes the principal conclusions and recommendations of the study.

Volume 2. HAZARDOUS PAYLOADS SURVEY AND ANALYSIS: This volume presents the results of a survey and analysis of proposed Shuttle payloads to identify hazardous payloads and define the characteristics of materials and systems which make them hazardous. This task included the development of a hazardous payloads ranking technique and recommendations for processing analysis on selected payloads.

Volume 3. NORMAL PROCESSING ANALYSIS: This volume presents preliminary normal processing flow plans for three Shuttle cargoes selected as a result of the Hazardous Payloads Survey and Analysis Task. These three cargoes are:

- Spacelab with Advanced Technology Laboratory,
- Tug, Solar Electric Propulsion Stage, and Synchronous Earth Observatory Satellite, and
- Interim Upper Stage and a Pioneer Jupiter Probe with a Fluorine Propulsion Unit.

The preliminary processing flow plans include identification of unique facilities and GSE, processing hazards, and payload safety related design criteria.

Volume 4. CONTINGENCY PROCESSING ANALYSIS. This volume presents preliminary alternate processing flow plans for contingency situations for the three Shuttle cargoes analyzed in the Normal Processing Analysis Task.

Volume 5. CURRENT PAYLOADS SURVEY AND ANALYSIS: This volume presents the results of a survey and analysis to determine payloads that are currently flying and that may also fly on the Shuttle vehicle when it becomes operational. The analysis determines hazardous materials/systems for each of these current payloads and recommends design and operational safety criteria for each hazardous current payload to minimize its impact on the Shuttle Transportation System.

Volume 6. ENVIRONMENTAL IMPACT STATEMENT POTENTIAL REQUIREMENTS: This volume presents the results of an evaluation of the probable environmental impact of Shuttle payloads hazardous materials and includes recommended KSC Environmental Impact Statement Potential Requirements.

Volume 7. ADVANCED TECHNOLOGY REQUIREMENTS: This volume presents a list of special problems identified in the study which require advanced technology study or technology development.

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1.0 INTRODUCTION

Payloads containing hazardous materials associated with space vehicle launch operations have been recognized and dealt with on previous R&D space programs. However, when compared to the Shuttle Program, these R&D space programs involved relatively few launches with considerable time between launches. The Shuttle operational program will have a high launch rate and in many cases individual launches will have several independent payloads for accomplishment of separate missions. Some of these payloads by intent will be recoverable for purpose of reuse, and all must be recoverable in the sense that possible abort situations prior to deployment have to be recognized.

Present processing schedules have been derived assuming nominal passive payloads and nominal payload flow time. A number of specifically safety oriented studies on Shuttle payloads has been performed in recent years. However, relatively few of these have treated ground operations in depth, and the overall impact of Shuttle payload hazards on launch and landing site processing and procedures has not been documented. In order to fill this gap, this ten month study was initiated in July 1974. The overall study objectives were to uncover and determine the hazard potential of Shuttle payloads, develop safety oriented normal and contingency launch site processing plans for selected cargoes that will minimize the impact on cost and schedules, and provide for environmental protection.

1.1 TASK OBJECTIVES

The purpose of the normal processing analysis task was to develop and analyze normal launch site processing flows for each of the cargoes selected as a result of the hazardous payloads survey and analysis task. These three cargoes are:

- Spacelab with Advanced Technology Laboratory (ATL) and Integrated Real Time Contamination Monitor (IRTCM).
- Tug, Solar Electric Propulsion Stage (SEPS), and Synchronous Earth Observatory Satellite (SEOS).
- Interim Upper Stage (IUS) and a Pioneer Jupiter Probe (PJP) with a Fluorine Propulsion Unit (F_2PU).

This task included the development of normal processing flow plans to a level necessary to identify all processing hazards, time lines, unique facilities and Ground Support Equipment (GSE) requirements, safety requirements for launch site protection, and payload safety related design criteria.

1.2 SCOPE

The normal processing analysis task analyzed all processing operations relative to receiving, storing, test and checkout, integration with the Orbiter and/or upper stage, launch preparations, and landing and refurbishment at the launch site for the three cargoes selected as a result of the hazardous payloads survey and analysis task.

1.3 TASK APPROACH

Figure 1 illustrates the analysis approach for the normal processing and hazards analysis of the three cargoes selected and approved by KSC for analysis in this task.

The philosophy was to develop a processing plan that was a balance between safety considerations and processing constraints. Our goal was to minimize on-line processing and at the same time minimize personnel exposure to hazards, minimize exposure of payloads to other payload hazards, and minimize Orbiter exposure to payload hazards.

In developing the normal processing flow, the first step was to develop a processing scenario for each cargo showing the major processing steps and processing locations. Data from KSC's Launch Site Accommodations Handbook for Shuttle Payloads were used as a basis for developing the initial top-level scenarios. KSC Shuttle Operations Planning Office's time line allocations along with facilities planning data from the Shuttle Projects Office and discussion with KSC personnel were used as additional information sources for developing the scenarios.

A top-level flow was then developed to show individual payload operations, cargo operations, launch operations, and post-launch operations. This top-level flow is essentially an index of operations at different areas and was expanded into a detailed operational sequence for each cargo. This was an iterative process and the normal base line flows were revised several times.

For each individual operation on the normal flows, a functional event sheet was prepared to define the operation to a level necessary to identify all hazards, estimate operations times, and identify GSE. For each hazard identified, a Hazard Mode Effects Analysis (HMEA) was performed to determine the potential hazard effect. A support equipment listing was prepared for the GSE and facility requirements for processing

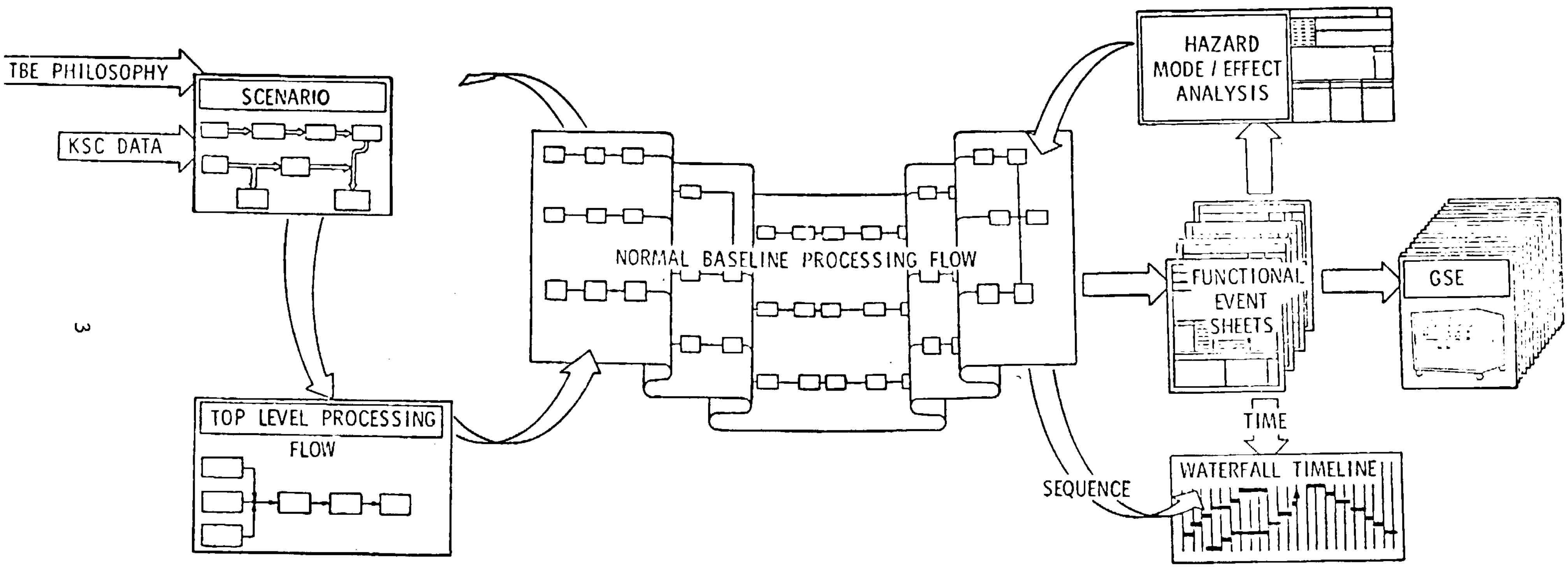


FIGURE 1. ANALYSIS METHODOLOGY

operations that were identified. From this listing, a support equipment identification sheet was prepared for the items that were new, peculiar, or associated with hazardous operations.

A waterfall/time line chart was prepared to show the normal processing sequence of operations and the processing time line. The time lines noted in this report are not valid in every case because they were obtained in the early part of the study and have since changed. The time lines, however, have no impact on the intent of the study. For the latest valid times to correlate with specific Teledyne Brown Engineering (TBE) time lines, see the following documents:

NAME OF DOCUMENT	CONTACT
KSC Spacelab Operational Turnaround Allocation, March 17, 1975	F. Bryan, LO
Shuttle/Tug Turnaround Allocation, December 16, 1974	Don E. Phillips, SP-OPN
Level III Shuttle Turnaround Allocation Payload Installation at Orbiter Processing Facility, April 1, 1975	Don E. Phillips, SP-OPN
Level III Shuttle Turnaround Allocation Payload Installation at Launch Pad, April 1, 1975	Don E. Phillips, SP-OPN

1.4 SUMMARY OF RESULTS

1.4.1 Cargo Hazards

The three cargoes' normal base line processing flows and functional event descriptions resulted in the identification of 28 different types of hazards distributed throughout 237 operational events. An analysis of each event, of the operations involved, and of the hazardous systems was performed to determine the effect of the hazard on personnel, facilities, payloads, Orbiter, and the environment. To reduce or eliminate the effects of the payload hazards, 87 payload design recommendations were made, 125 safety related operational requirements were identified, and 57 items/requirements for support equipment were generated. The hazards that were identified for each of the three cargoes, the frequency of occurrence, and the final hazard categorization are shown in Table I.

TABLE I. CARGO HAZARDS SUMMARY

Hazard Types	Frequency of Occurrence Spacelab	Tug	IUS	Final Hazard Categorization
High Pressure	7	18	15	Catastrophic
Cryogenic F_2 Overpressure			5	1 Catastrophic and 4 Critical
Hydrazine & Methyl Derivatives		6	5	Critical
Mercury		2		Critical
APS Thruster Firing - Toxic Gas		2	2	Critical
Cryogenic O_2		3		Critical
Cryogenic H_2		4		Critical
GF_2			1	Critical
Cryogenic F_2			2	Critical
N_2O_4			2	1 Critical and 1 Controlled
GN_2 Purge	1	15	6	Controlled
Electrical Power	6	26	13	Controlled
RF Emissions		4	3	Controlled
Laser	2	1		Controlled
High Temperature		1	1	Controlled
Moving Equipment		1		Controlled
Freon	3			Controlled
Pyrotechnics - Safed		5	2	Controlled
Pyrotechnics - Armed	2	2	1	Controlled
Batteries		4	1	Controlled
Hydraulics		1		Controlled
Purge with Hot GN_2		1		Controlled
Radar	2			Controlled
Steam Generator	2			Controlled
Microbiological	3			Controlled
Cryogenic N_2			5	Controlled
Radiological			2	Controlled
Krypton 85			2	Controlled

1.4.2 Interface Hazards

Those operational events containing more than one hazard and those operations where hazards were continued from previous events were examined for possible interface hazards.

In the Spacelab/ATL/IRTCM cargo, two events were found to present an interface hazard potential and both of these involved electrical power application checks that could lead to the inadvertent activation of other hazardous sources such as laser, radar, or steam generator.

The major interface hazards for the IUS/F_2PU/PJP cargo are centered around fluorine and other hypergolic materials such as hydrazine and N_2O_4. The potentially catastrophic effect of a water leak from the Radioisotope Thermoelectric Generator (RTG) cooling jackets combining with a fluorine leak is also an interaction hazard. Fluorine leakages could adversely affect critical electronics and control circuits.

In the Tug/SEPS/SEOS cargo, the 10 events found to present an interface hazard potential had as their common causative or accessory hazard the application or use of electrical power. Electrical power application usually involves checks, tests,and/or verification of various communications networks, control systems, and interfaces. The electrical power application can lead to the inadvertent activation of other hazardous sources, such as RF generating systems, lasers, heaters or thruster gimbals. Mercury leakage could also cause electrical shorts, arcing, and affect critical circuits.

In all cargoes, the application of electrical power or malfunction in an electrical system could lead to the ignition of spilled or leaking fuels. Similarly, inadvertent power application to pyrotechnic devices could result in the ignition of other fuel sources. Finally, the presence of propellant reactants (LO_2, LH_2, LF_2, N_2O_4, and N_2H_4) presents a potentially catastrophic situation if simultaneous leakages should occur.

1.4.3 Time Line Analysis

The time line analysis conducted revealed that no Orbiter constraints are imposed. For safety reasons, it was necessary to perform off-line loading of fluorine in the F_2PU. This operation involves passivation, loading, stabilizing, and monitoring, which is a 31-hr operation. Obviously, without off-line fluorine loading the Orbiter processing would have been impacted.

1.4.4 GSE/Facility Identification for Normal Processing

Fifty seven items of GSE/facility were identified for the normal processing of all three cargoes. The items that may cause a significant impact on KSC are as follows:

- GSE
  - --IUS/F_2PU Cargo Transporter (LN_2 Dewar and Monitoring System)
  - --Portable Fluorine Disposal Unit and LN_2 Dewar for use at:
    - -Fluorine Loading Facility
    - -SAEF #1
    - -Launch Pad
  - --Personal Life Support Equipment Compatible with Fluorine
  - --Fluorine Sensing Systems
  - --Mercury Servicing Unit
  - --Mercury Sensing Systems

- Facilities
  - -- Dedicated Fluorine Facility
  - -- Hydrazine APS Dedicated Loading Area in SAEF #1
  - -- Mobile Biological Holding Facility
  - -- Laser Test Facility

1.4.5 Principal Conclusions and Recommendations

The primary findings, conclusions, and recommendations that resulted from this task are as follows:

- Fluorine

  -- Because of the hazardous characteristics of fluorine and the time required for passivations, loading, and thermal stabilization (31 hr) fluorine loading should be performed off line.

  -- A special fluorine loading facility designed/dedicated only to fluorine loading/unloading is required to provide personnel and environmental protection during this hazardous operation.

  -- The fluorine loading facility will require almost continual maintenance/service between periods of usage to maintain the facility in a condition that can safely handle F_2. This is due to the corrosive and reactive nature of fluorine that requires that all lines, tanks, valves, etc., be maintained in a dry inert condition, and that after each use, the system be completely purged to remove F_2 in order to prevent severe corrosion. If these are relatively long periods between use, it may be necessary to disassemble and inspect a large part of the facility before use.

  -- The fluorine propulsion unit oxidizer system should be designed to allow in-space pressurization (to operating pressure).

  -- The F_2PU must be designed such that it can be processed as a separate unit from the PJP.

-- Onboard LN_2 cooling system for F_2PU will be required to maintain thermal balance and pressure level until the unit is in orbit.

-- Ground cooling with LN_2 is required through the Orbiter T-0 umbilical to reduce the required supply of onboard supply of LN_2 cooling.

- Mercury

  -- Mercury propellant should be loaded off-line in an area to prevent spills from contaminating the facility, Orbiter, other payloads, or the environment. This is primarily due to the dispersive nature of mercury and difficulty in cleanup.

  -- Mercury servicing provisions should be provided by a portable servicing unit and should include storage tank, valves, lines, etc.

  -- A vacuum system with a filtered exhaust for spill cleanup, a vacuum pipette system for picking up small particles, splash pans and spill aprons should also be provided for mercury servicing.

- Microbiological Species

  -- Biological sample containers for transfer and flight must be fail safe (double walled, and include biocide to render specimens harmless if inside container is damaged).

  -- A biological facility and mobile biological unit will be required for preparation and transporting biological/ microorganisms to prevent release of any pathogenic hazards.

  -- Trained and equipped biological survey/decontamination teams will be required.

- Radiological - RTG's

  -- Cooling Requirements

    - External water cooling system must be provided for pad operations (recommend through the Orbiter T-0 umbilical).

  - Requires onboard water cooling system.

- -- Radiation Exposure Hazards

  - Special handling equipment, fixtures and facilities required to limit radiation exposure of operating personnel.

  - Unit(s) must be installed in cargo/Orbiter as late in processing sequence as possible to limit radiation exposure of personnel.

- General

  - -- Final pressurization of high pressure systems must be performed at the pad late in the countdown (before crew boards).

  - -- Final pressurization of hazardous fluid systems should be pressurized as late in the mission as possible. Performing this operation just before deployment into space from the Orbiter for APS and after deployment in space for MPS. This requires that all hazardous fluid systems design have regulated pressurizing systems (no blowdown systems).

  - -- All hazardous fluid systems should be pressure and leak checked to operating pressure at KSC during ground operations before loading. All high pressure systems should be pressure and leak checked at KSC before installation in the Orbiter.

  - -- It is recommended that the use of pyrotechnic devices in payloads be minimized because many payloads have RF generating devices (Radar, Lidar, Antenna's, etc.). It is desirable that access to all payload pyrotechnics Class A devices (EED's, etc.) be provided so that connection could be performed after installation in the cargo bay and disconnection could be performed before removal in case of a pad backout.

  - -- Hazardous payloads systems and experiments which generate RF, laser beams, heat, or other energy sources should have multiple interlocks to prevent inadvertent actuation.

-- Special facilities, covers, protection, etc. should be provided for energy generating equipment (RF, Laser, etc.)--i.e., laser test facility, antenna covers, RF shields, etc.

2.0 SPACELAB/ATL CARGO PROCESSING PLAN

2.1 CARGO DESCRIPTION

The cargo consisting of Spacelab, ATL experiments, and the IRTCM experiment is the presently scheduled payload for the fifth operational flight of the Shuttle flights and is designated Shuttle Mission 11 in the schedule for the first 2 years of Shuttle flights. The purpose of this Shuttle mission is to deliver the first ATL, equipped by the Langley Research Center, to orbit and perform a 7-day Sortie mission. The ATL payload will make use of the space environment (e.g., high altitude and velocity, weightlessness, and radiation) to develop and test a wide variety of advanced technology systems and techniques.

The flight hardware for this cargo consists of the following major elements:

- Transfer Tunnel
- Core/Experiment Segment
- Rack/Floor Assemblies
- Pallet
- ATL and Contamination Monitoring Experiments

Sketches showing the ATL, location of ATL/Spacelab in Orbiter,and ATL/Spacelab Pallet configuration for this mission are presented in Figures 2 through 4. This configuration provides a pressurized volume for support systems and experiments and a pallet for mounting experiments to be conducted in the environment of space. The experiment/pallet/module groups can be handled as an integrated unit and can be installed in or removed from the Orbiter as a unit.

2.1.1 ATL and Contamination Monitoring Experiments

The payload for this flight consists of 13 experiments selected from ATL payloads and the IRTCM experiment. The experiment payload consists of the following experiments:

- Microwave Interferometer Navigation and Tracking Aid
- Autonomous Navigation

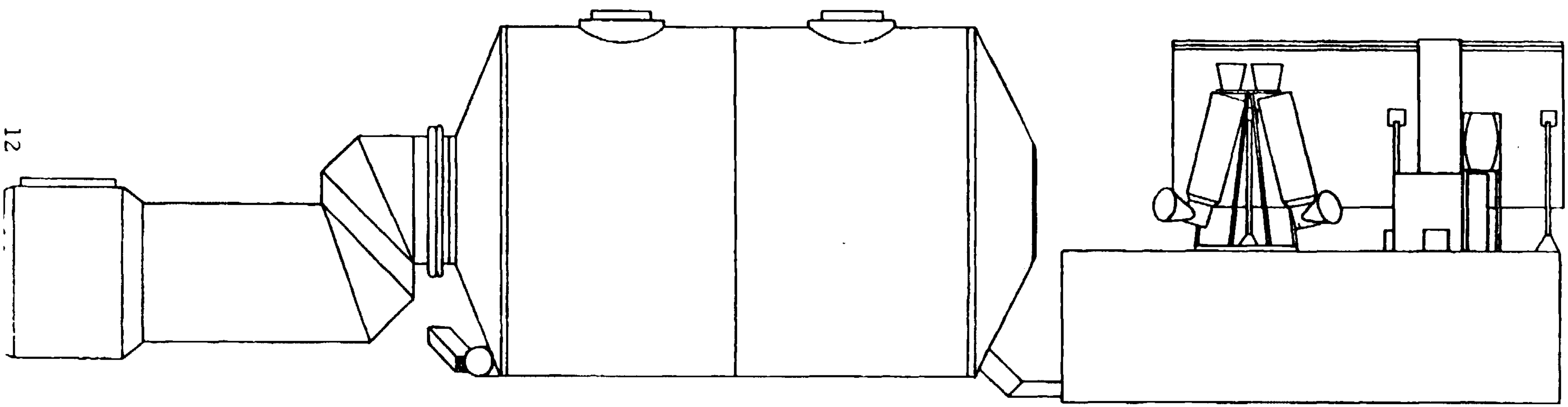


FIGURE 2. ADVANCED TECHNOLOGY LABORATORY

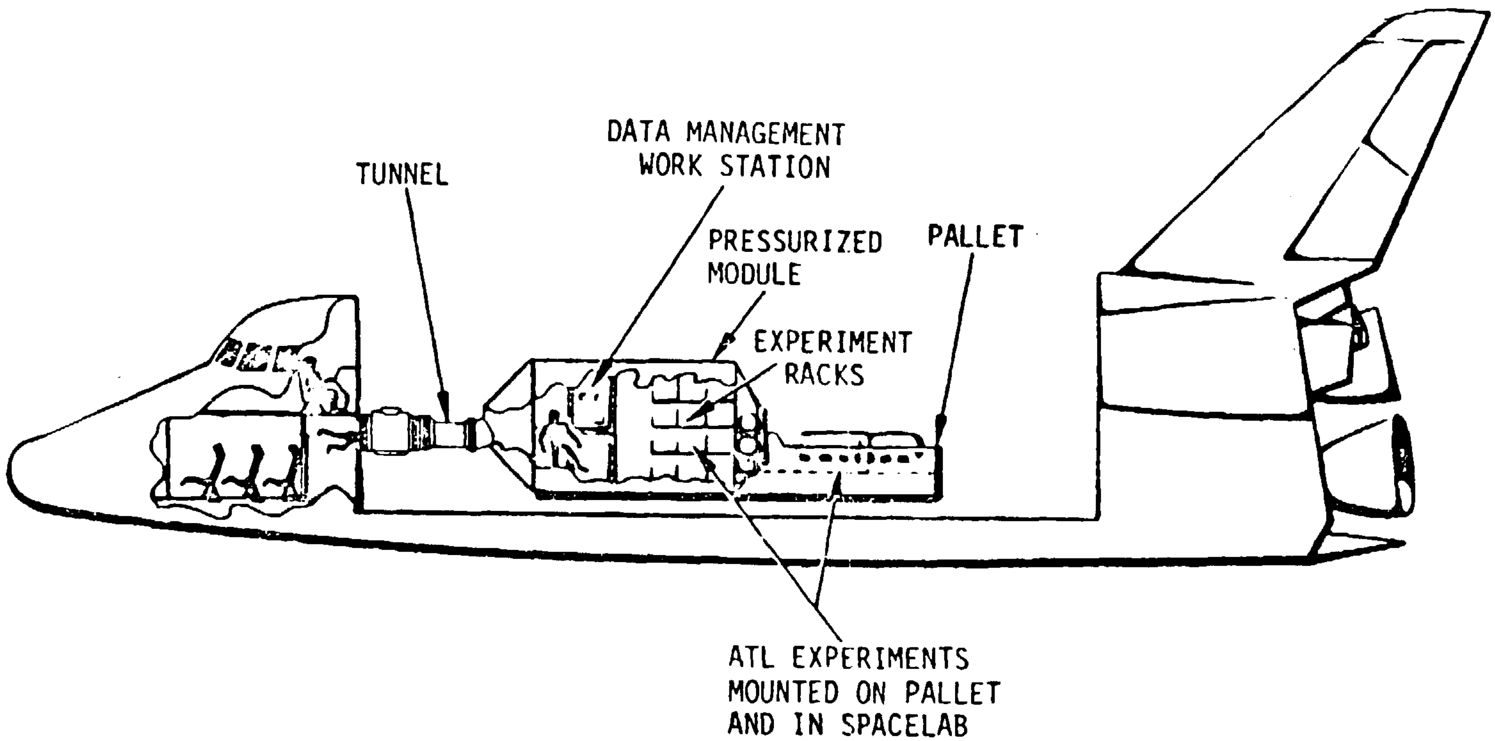


FIGURE 3. ATL/SPACELAB LOCATION IN ORBITER

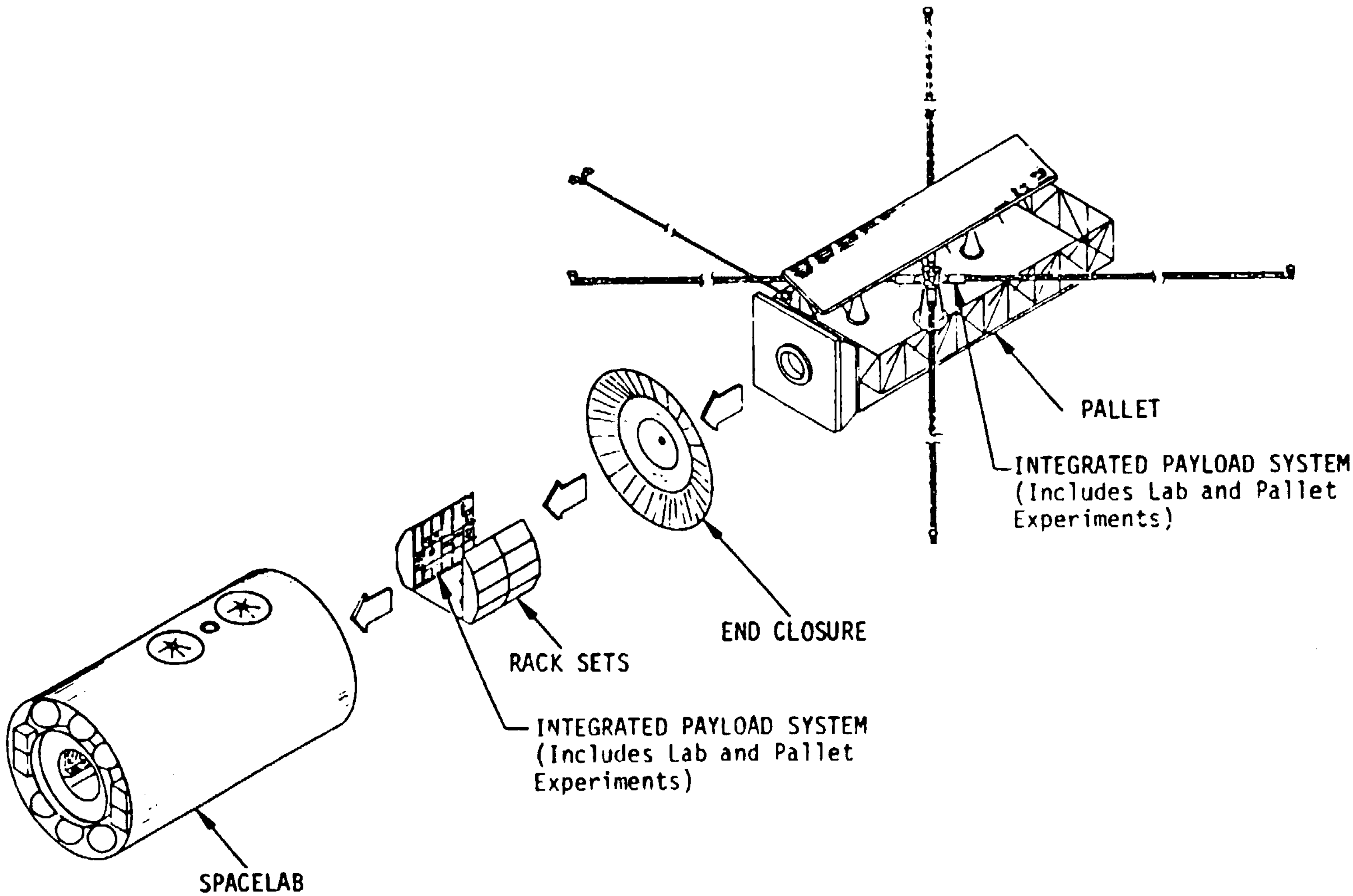


FIGURE 4. ATL/SPACELAB/PALLET CONFIGURATION

- Search and Rescue Aids
- Imaging Radar
- Lidar Measurement of Cirrus Clouds and Lower Stratospheric Aerosols
- Ultraviolet Meteor Spectroscopy from Near Earth Orbit
- Colony Growth in Zero Gravity
- Interpersonal Transfer of Microorganisms in Zero Gravity
- Electrical Characteristics of Cells
- Special Properties of Biological Cells
- Zero Gravity Steam Generator
- Sampling of Airborne Particles and Microorganisms in Space Cabin Environment
- Environmental Effects on Nonmetallic Materials
- IRTCM.

2.1.2 Summary of Hazardous Materials/Systems

The Spacelab/ATL/IRTCM cargo will require checkout and servicing during processing. The following hazardous materials/systems are carried by this cargo and are of concern in processing:

- Electrical
- Radar
- Laser
- Freon
- Steam Generator (water and silicone)

- High Pressure GN_2
- Pyrotechnics (boom jettison systems)
- High Pressure GO_2
- Microorganisms

2.2 PROCESSING SCENARIO

The Spacelab/ATL/IRTCM processing scenario is presented in Figure 5. This scenario presents the following sequence of operations:

- The ATL experiments and experiment peculiar GSE are off-loaded at the KSC air strip and transported to the O&C Building where they are inspected, functionally tested, and integrated with the Spacelab elements.
- The integrated Spacelab/ATL/IRTCM is transported to the Orbiter Processing Facility (OPF) where it is mated to the Orbiter and the Orbiter integrated tests are conducted.
- The Orbiter/cargo is then moved to the Vertical Assembly Building (VAB) for Shuttle final assembly and verification. After verification, the mobile launcher platform is moved from the VAB to the pad.
- At the pad, the experiment time critical elements are installed, final servicing is conducted, and countdown is initiated.
- After normal mission flight and in-flight safing operations, the Orbiter lands at the Orbiter airstrip where safing operations are conducted.
- The Orbiter is moved to the OPF where the time critical elements and Spacelab are removed from the Orbiter.

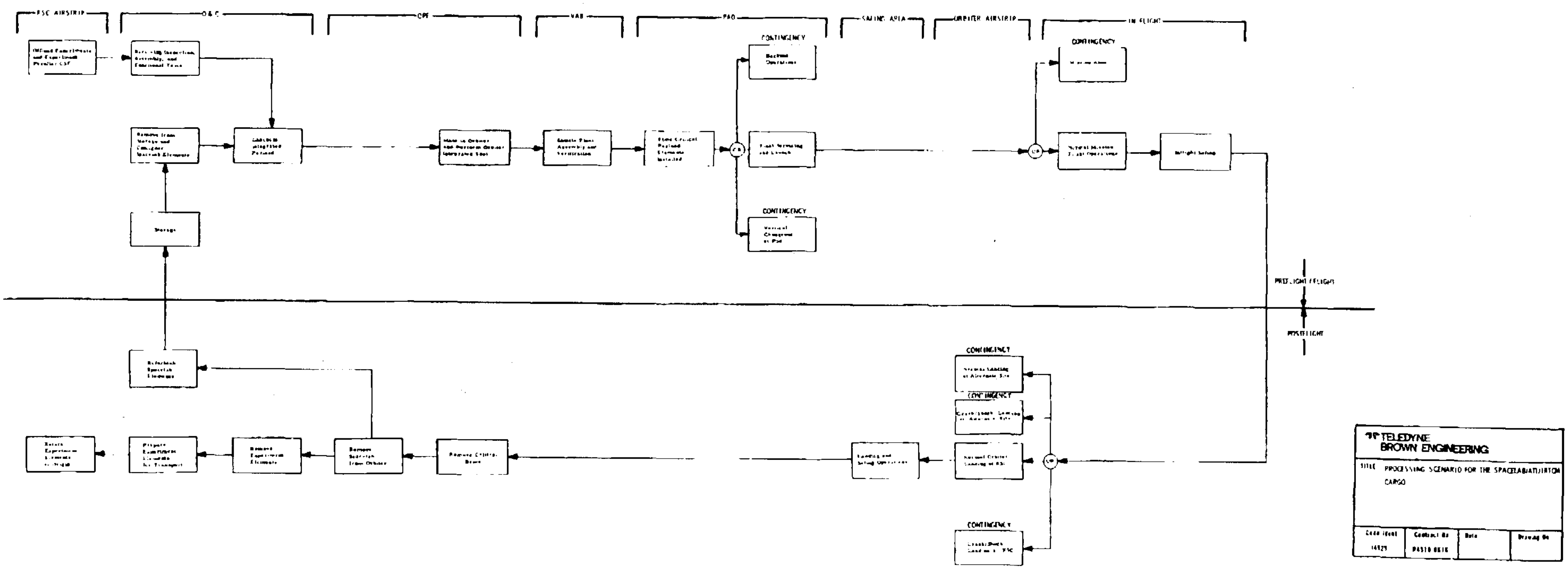


FIGURE 5. PROCESSING SCENARIO FOR THE SPACELAB/ATL/IRTCM CARGO

- The experiment elements are removed and the Spacelab is disassembled in the O&C. The experiment elements are prepared for transporting and are returned to their respective vendors for refurbishment. The Spacelab elements are refurbished and either sent to storage, or put back into operation.

In addition to the normal processing scenario discussed, six contingency situations are presented. Two contingency situations at the Pad are shown:

- Backout Operations
- Vertical Changeout

The third contingency, Mission Abort, is shown as an alternative to the normal in-flight operations. The fourth, fifth and sixth contingencies are:

- Normal Landing at Contingency Site
- Crash/Shock Condition Landing at KSC
- Crash/Shock Condition Landing at Contingency Site

These are presented as alternatives to the normal landing operations at KSC and contingency flow plans for these situations are included in Volume 4.

2.3 PROCESSING FLOWS

This section presents the Spacelab/ATL/IRTCM Launch Site Processing Flow Plans that were derived during this study. These flow plans identify each major operation necessary to prepare the payload for flight and post-flight refurbishment and acknowledge the payload hazardous parameters that exist during these operations.

A top-level flow was developed to show individual payload operations, cargo operations, launch operations, and post-launch operations. This top-level flow is essentially an index of operations at different areas and was expanded into a second level flow,which is a detailed operational sequence for each cargo. Development of this flow was an iterative process,and through a series of iterative tradeoffs the normal base line processing flow plans were formed.

2.3.1 Top Level

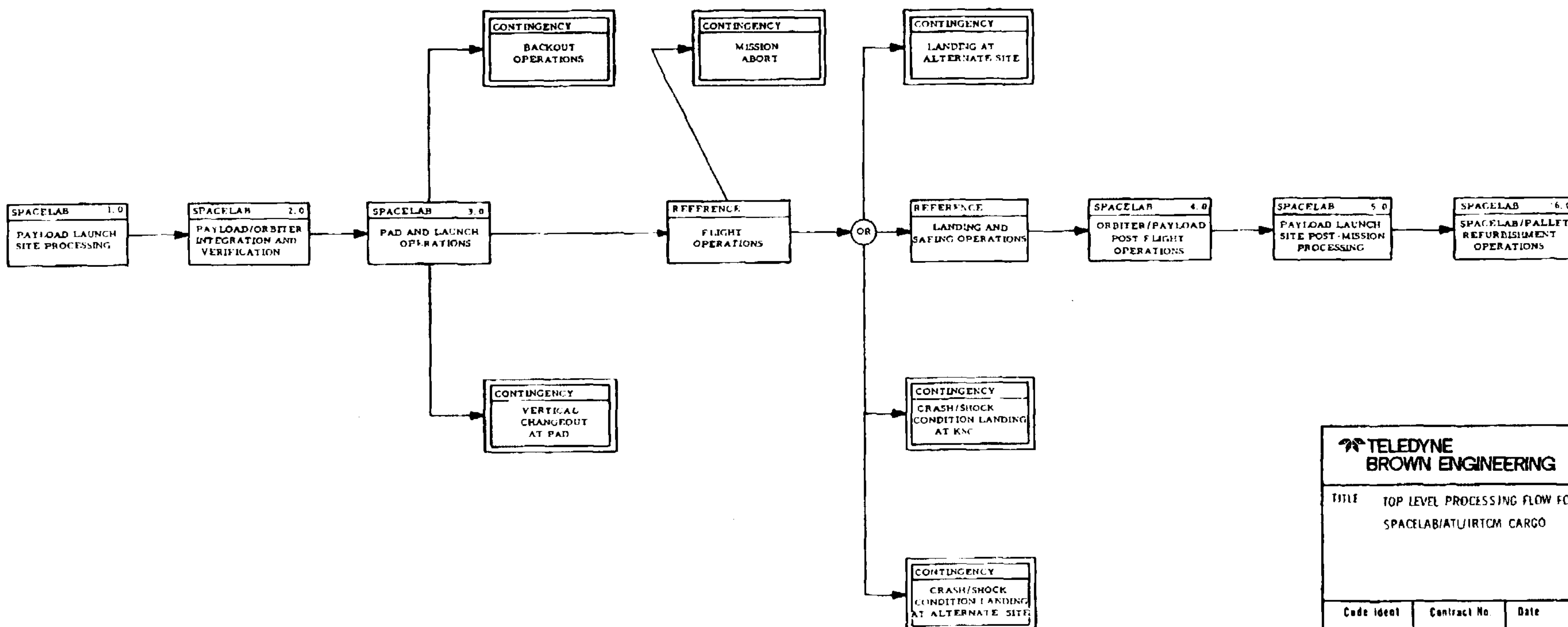
While the scenario for the Spacelab/ATL/IRTCM cargo shows basic and essential operations to enable its processing, a slightly different format was established to be used as a top level functional flow. The top-level Spacelab/ATL/IRTCM Launch Site Processing Flow Plan shown in Figure 6 is an index of processing operations. This figure shows six major areas that provide convenient breakouts for the second level functional flows and have been addressed at the first level. The six major areas are:

- Payload Launch Site Processing
- Payload/Orbiter Integration and Verification
- Pad and Launch Operations
- Orbiter/Payload Post-Flight Operations
- Payload Launch Site Post-Mission Processing
- Spacelab/Pallet Refurbishment Operations

2.3.2 Normal Base Line

The Spacelab/ATL/IRTCM second level functional flow diagram referred to as the normal base line processing flow is an expansion of the first level with sufficient details to enable a hazards analysis to be performed from the second level functional event sheets.

The Normal Base line Processing Flow represents the output of an iterative process. Many feasible options in sequencing certain



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TITLE TOP LEVEL PROCESSING FLOW FOR THE SPACELAB/ATL/IRTCM CARGO

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FIGURE 6. TOP LEVEL PROCESSING FLOW FOR THE SPACELAB/ATL/IRTCM CARGO

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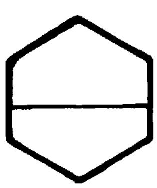
activities were examined to weigh their respective advantages and disadvantages considering the parameters of safety, time, and facilities. Through this process some hazardous operations were either eliminated, reduced, or replaced by less hazardous ones, or the sequence and/or locations changed so as to have a lesser impact. This process led to the evolvement of the normal base line processing flow. For each individual item on these flows, a functional event sheet was prepared to define the operation to a level necessary to identify all hazards, estimate operations times, and identify GSE.

Certain basic assumptions were made during the formulation of the normal base line processing flows:

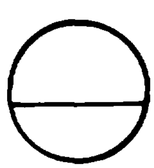
- It is assumed that an ordnance jettison system will be included in experiment design to eject the extended portions of experiments if they are not able to retract at the end of experiment operations.

- It is assumed that all these pyrotechnic devices can be installed and connected in the horizontal position prior to Orbiter payload bay door closing.

The Normal Base line Processing Flow for the Spacelab/ATL/IRCTM is shown in Figure 7. This processing flow covers the Spacelab processing from receipt at KSC through launch, landing, and refurbishment. Hazardous operations and hazard sources are indicated for each operation.



Hazardous operation, hazardous system activation, or termination of hazardous system operation. The hazard source and reference hazard analysis are shown.



Initiation of a hazardous operation or loading of a hazardous system which continues throughout subsequent processing operation or until terminated. The hazard source and reference hazard analysis are shown.

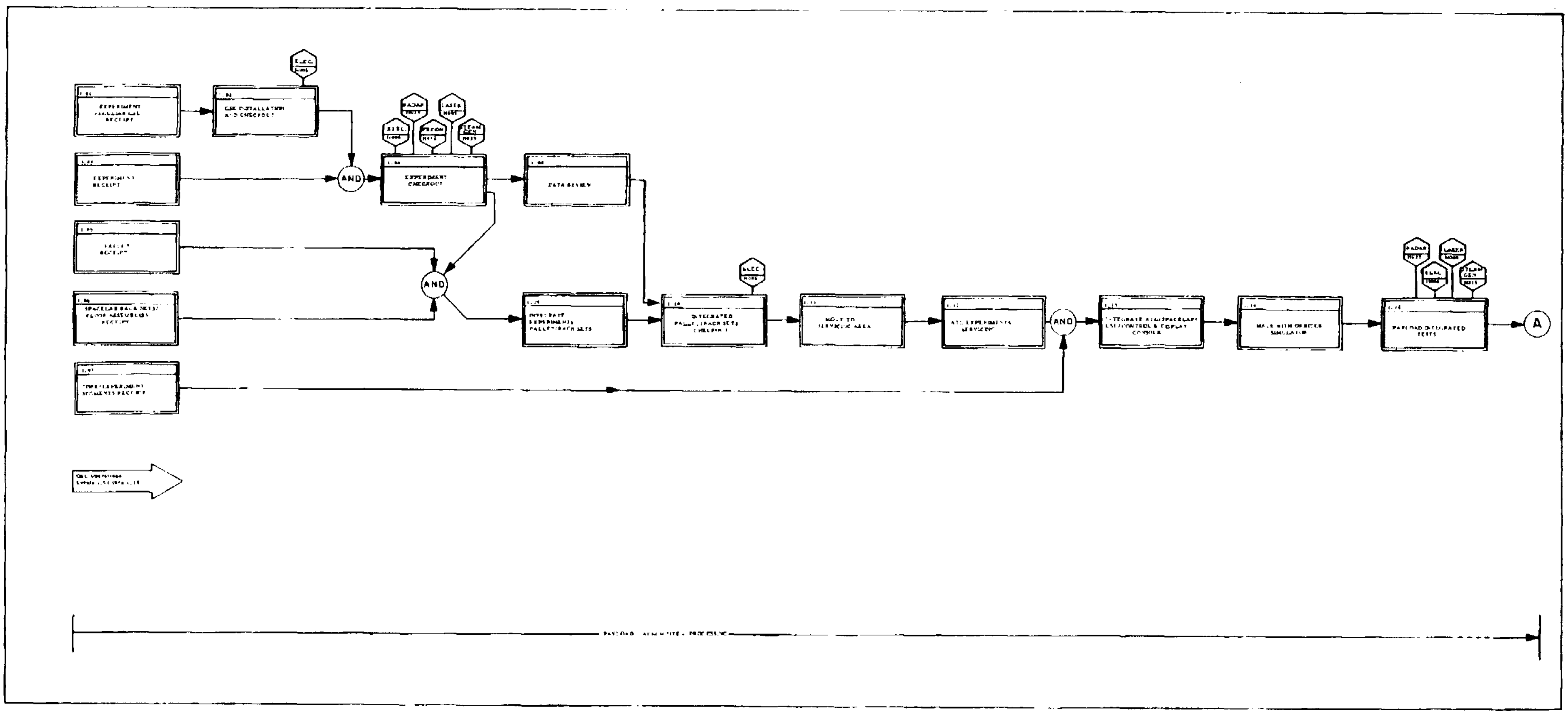


FIGURE 7. NORMAL BASE LINE PROCESSING FLOW FOR THE SPACELAB/ATL/IRTCM CARGO
(Sheet 1 of 6)

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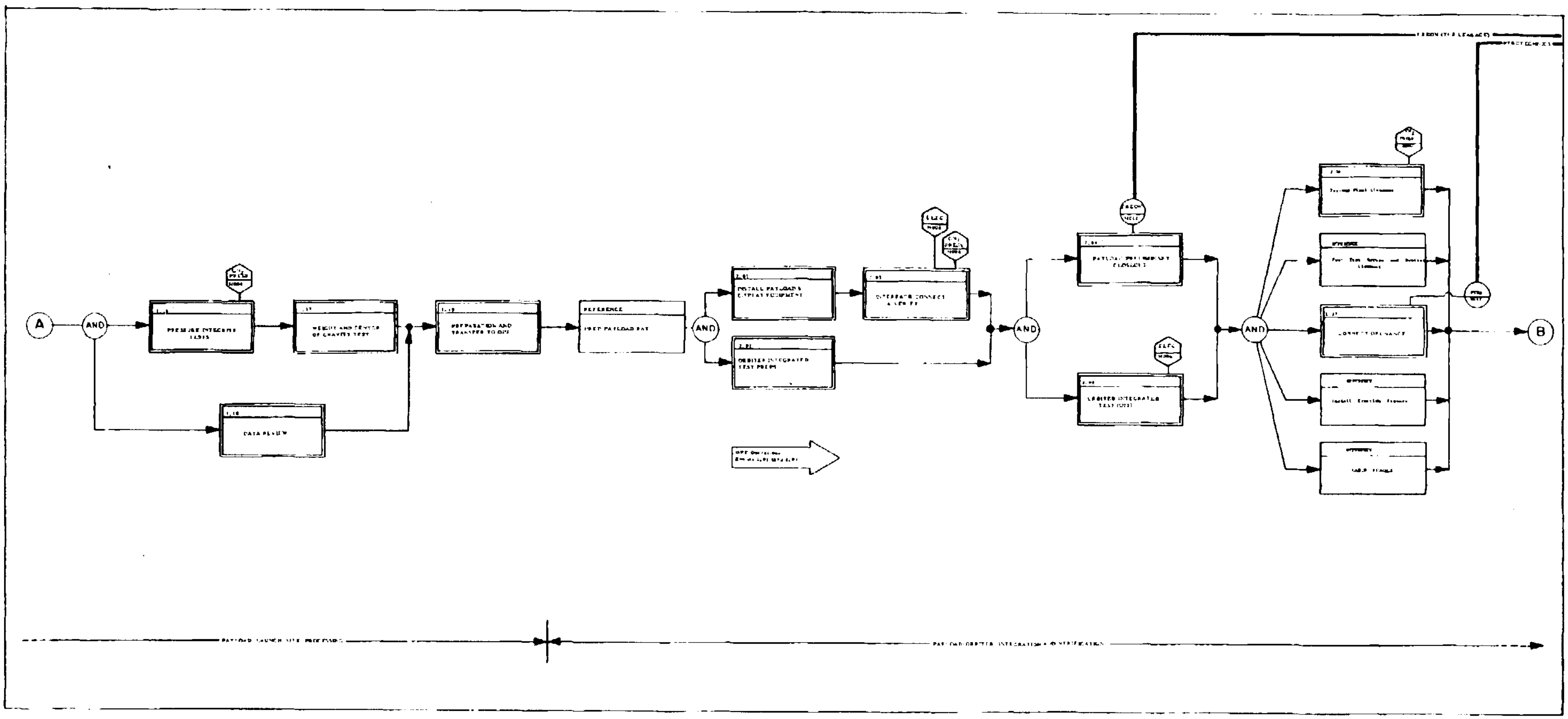

FIGURE 7. NORMAL BASE LINE PROCESSING FLOW FOR THE SPACELAB/ATL/IRTCM CARGO
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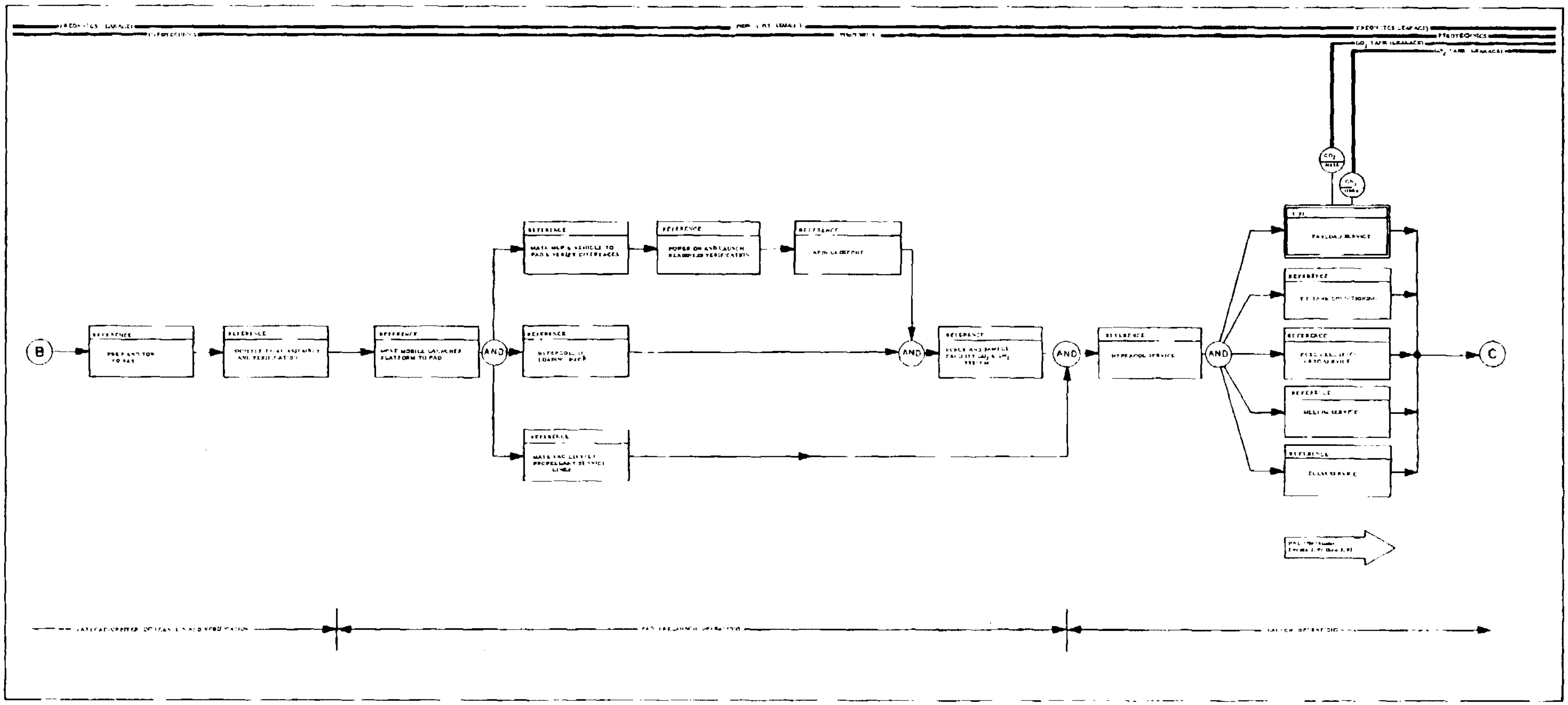

FIGURE 7. NORMAL BASE LINE PROCESSING FLOW FOR THE SPACELAB/ATL/IRTCM CARGO
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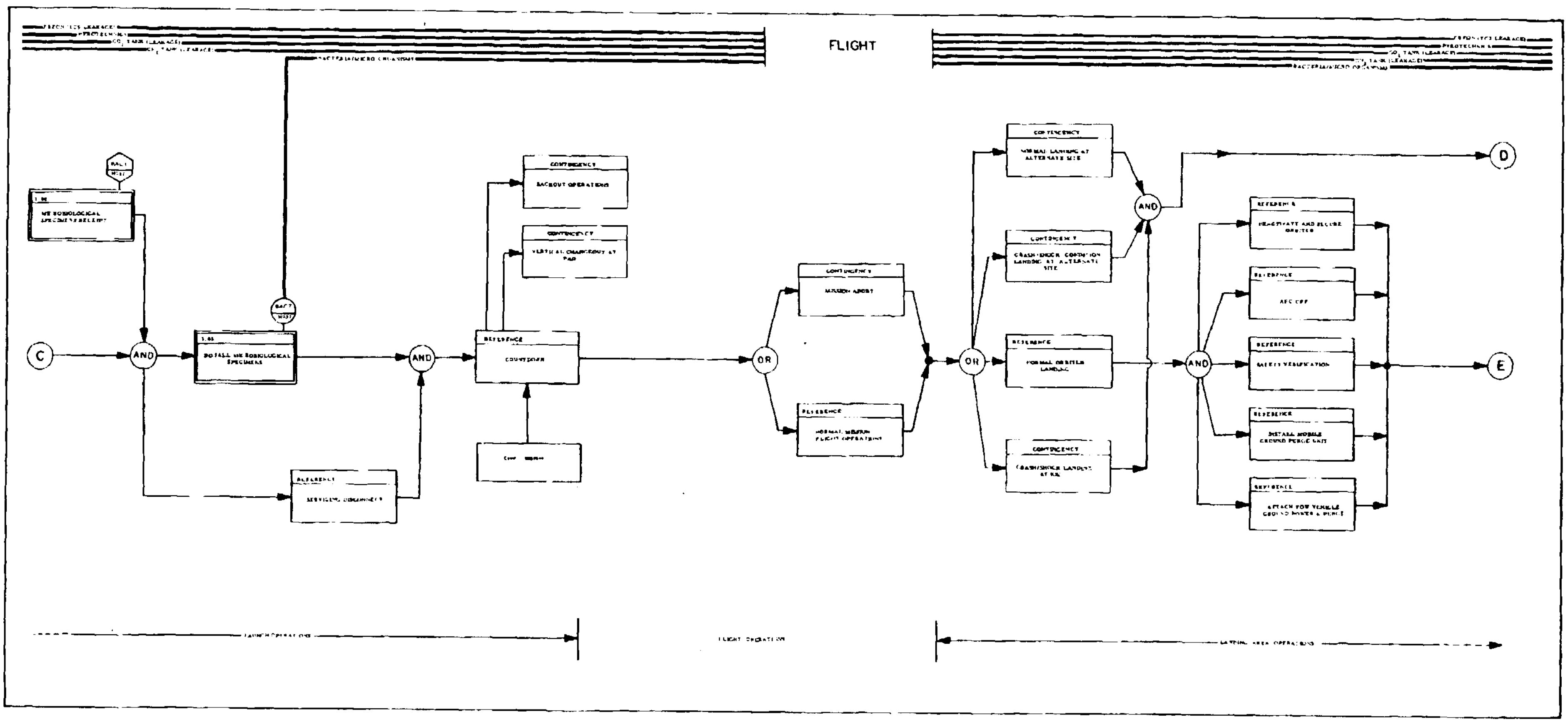

FIGURE 7. NORMAL BASE LINE PROCESSING FLOW FOR THE SPACELAB/ATL/IRTCM CARGO
(Sheet 4 of 6)

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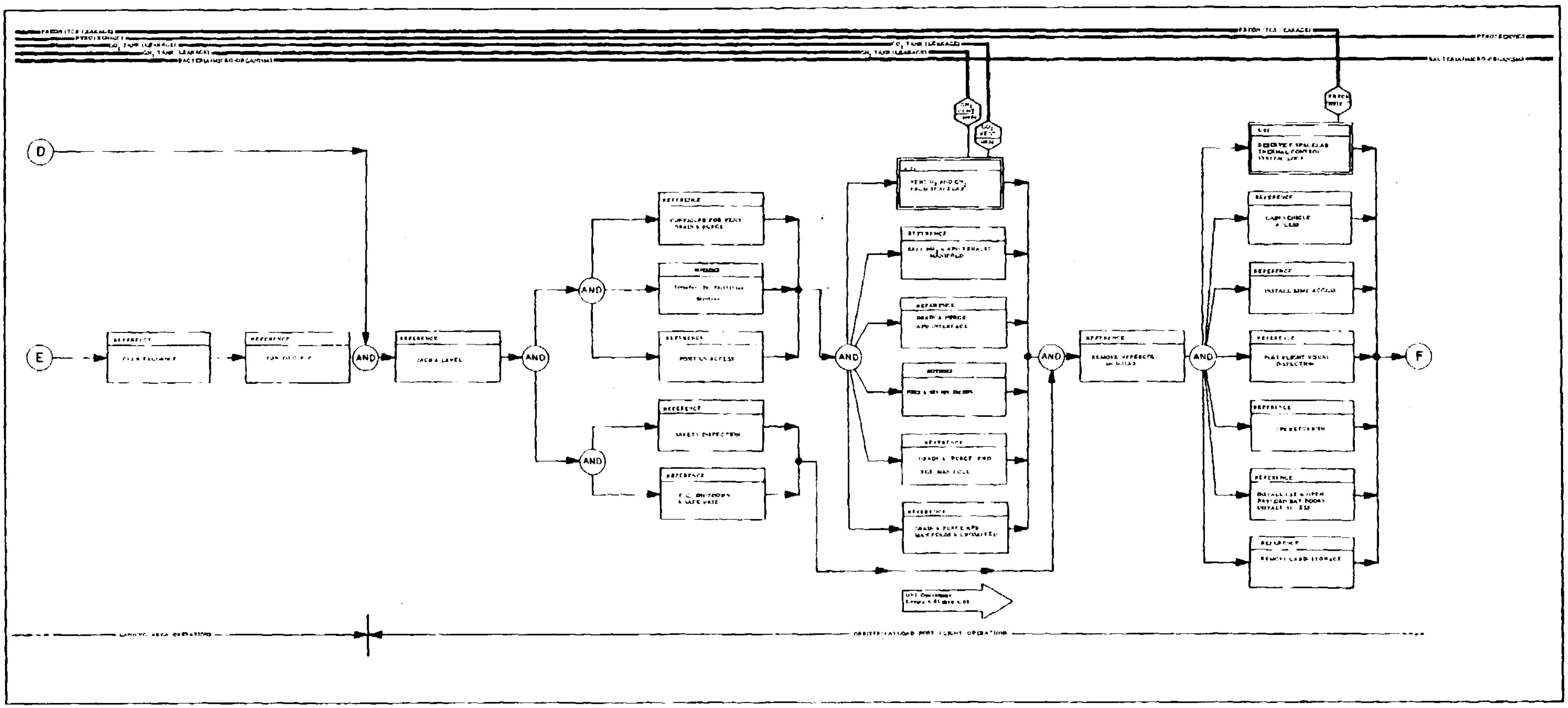

FIGURE 7. NORMAL BASE LINE PROCESSING FLOW FOR THE SPACELAB/ATL/IRTCM CARGO
(Sheet 5 of 6)

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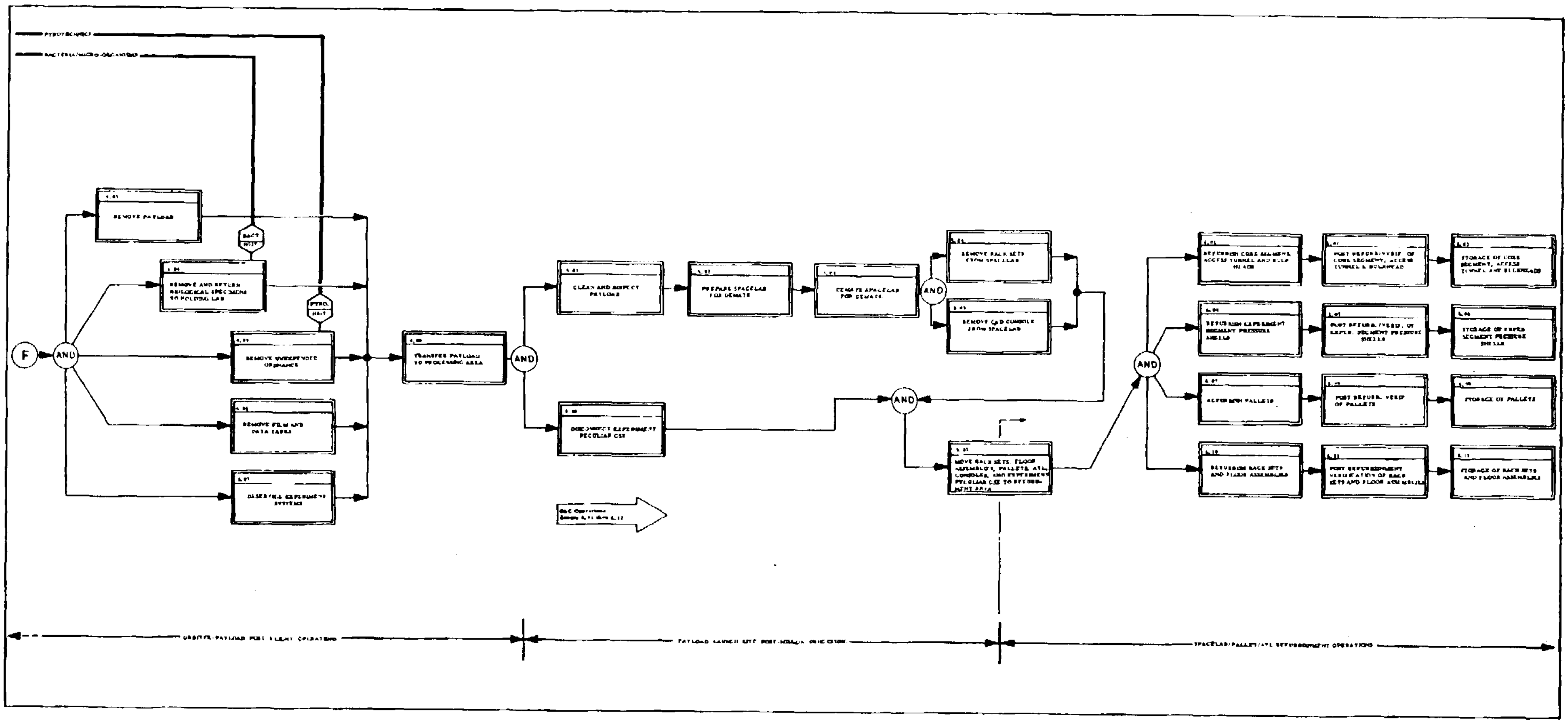

FIGURE 7. NORMAL BASE LINE PROCESSING FLOW FOR THE SPACELAB/ATL/IRTCM CARGO
(Sheet 6 of 6)

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2.3.3 Major Options to Normal Base Line and Tradeoff Studies

In the development of the normal base line processing flows, alternate flow plans were studied and analyzed to develop the optimum operational sequence of flow for processing the Spacelab/ATL/IRTCM cargo. These options present areas of the normal baseline processing flow concept that required additional study and tradeoff to ensure the selection and development of the most feasible and time/cost effective as far as safety aspects are concerned.

An area of concern for this cargo was the experiment biological specimen loading approach. Two options to the selected normal base line concept were investigated:

- Load specimens at OPF with Orbiter in horizontal position.
- Provide specimen refrigerator in Orbiter cabin.

The first alternate specimen loading approach is to load the specimens while in the OPF and in the horizontal position. This alternative requires continuous power to the Spacelab until launch, which is a potential hazard. It also requires monitoring the environment around the specimens until launch.

The other alternate approach would require the addition of a specimen refrigerator in the Orbiter cabin for storage during launch, after which the crew would carry the specimens to the ATL refrigerator under zero-g conditions. Here, of course, there are space and weight impacts on the Orbiter. The advantages of this method are that loading can be performed at the time of crew boarding. Removal can be performed during flight/crew exchange at the landing area. The disadvantage of this approach from a safety viewpoint is that if the biological samples are inadvertently released, the Orbiter cabin atmosphere can be contaminated.

2.4 FUNCTIONAL EVENT DESCRIPTION

The purpose of these functional event sheets are to describe each Spacelab/ATL/IRTCM processing operation, give the sequence of events required to complete the operation, and estimate the time required. For each event in the operation, potential hazardous conditions are noted and cross-referenced to a hazards analysis. GSE and facilities associated with this operation are also shown. Hazardous materials or systems loaded or activated in a previous operation are indicated by hazard category.

The operation sequence of events portion of these functional event sheets defines each of the Spacelab/ATL/IRTCM normal base line processing flow operations to a level necessary to identify all hazards, estimate operations times, and identify GSE. Fifty-seven normal base line processing flow operations were identified for the Spacelab/ATL/IRTCM cargo. Potential hazardous conditions were identified as being associated with 17 of these 57 operations.

The functional event sheets for the Spacelab/ATL/IRTCM normal base line processing flow operations are included in Appendix A.

2.5 WATERFALL/TIME LINE

The Spacelab/ATL/IRTCM Waterfall/Time Line provides a visual guide to the series and parallel relationship of the various processing flow operations. The processing flow operations were base lined early in this study in accordance with KSC Spacelab Operational Turnaround Allocation, August 28, 1974. These time lines were not updated by subsequent changes or modifications to the operational allocations since these changes were not detrimental to the results of this study.

The numbers and titles appearing on the events refer to the Spacelab/ATL/IRTCM normal base line processing flow diagram item.

2.5.1 Normal Base Line

The normal base line processing flow time line for the Spacelab/ATL/IRTCM cargo is illustrated in Figure 8. This cargo is received, checked out, and assembled in the O&C Building at KSC. This cargo is then moved to the OPF to be installed in the Orbiter cargo bay at approximately 91 hr prior to launch. The on-line processing operations require approximately 27 hr in the OPF and 38 hr in the VAB. The time at the pad for the cargo is approximately 17 hr.

Operations of interest for this cargo are loading an unloading of the biological specimens. These specimens must be refrigerated continuously. Therefore, they are not loaded until about T-4 hr, when the pad is opened after Orbiter servicing. At this time the spacecraft has power and the refrigerator is operational. Removal of the specimens

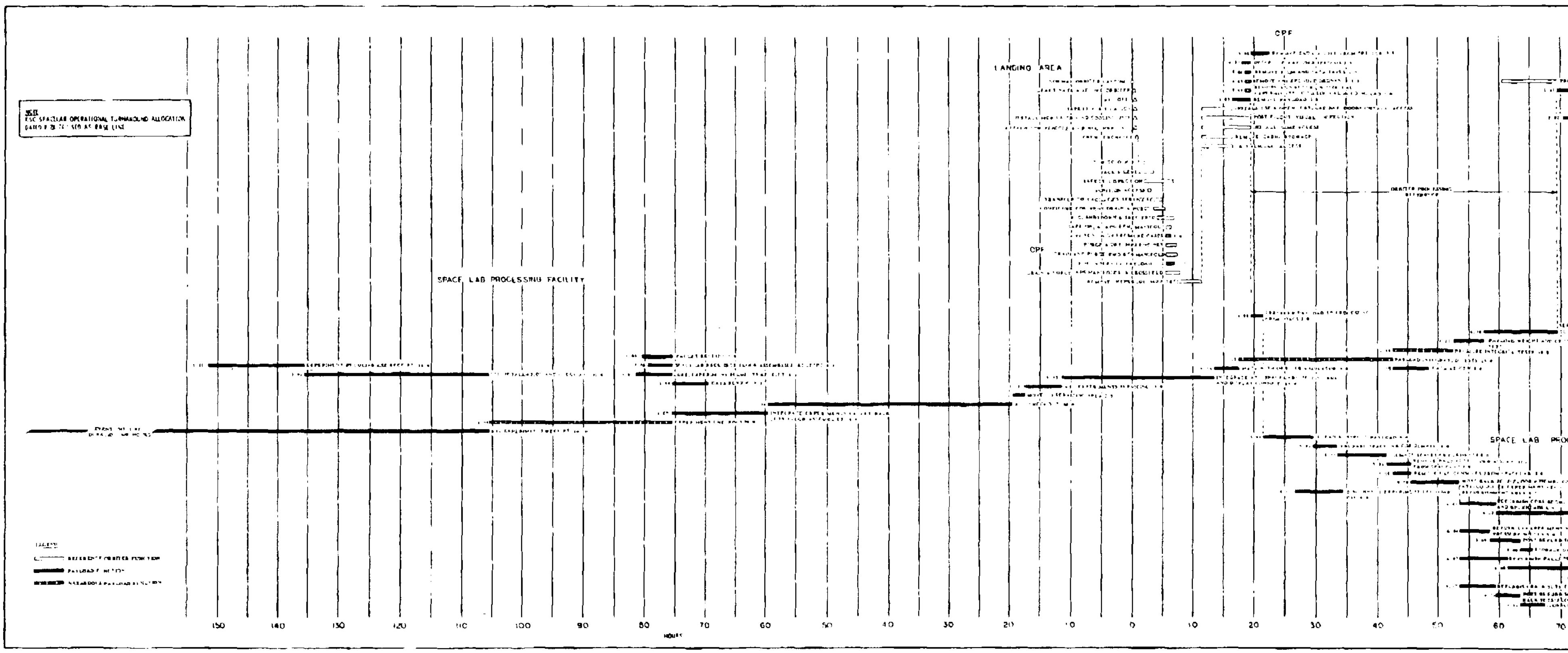
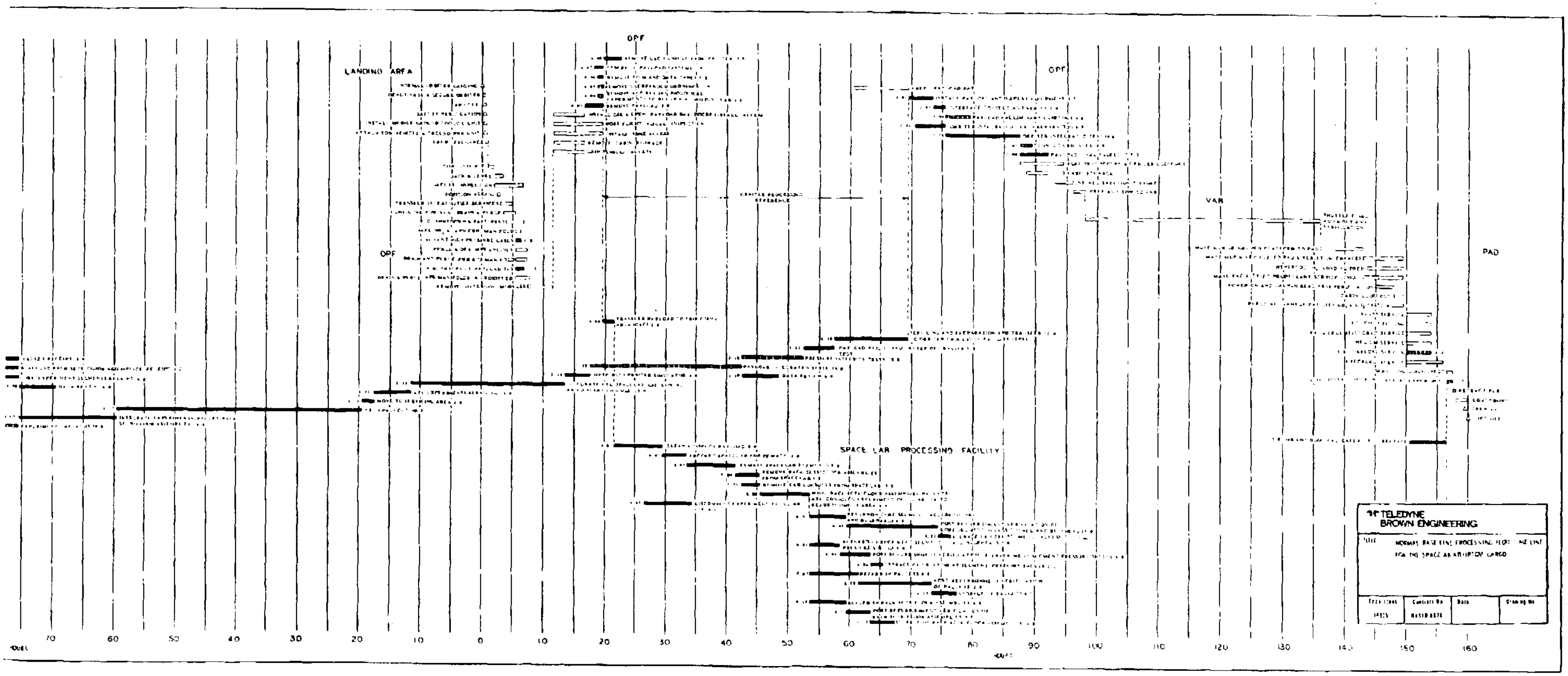


FIGURE 8. NORMAL BASE LINE PROCESSING FLOW TIME LINE FOR THE SPACELAB/ATL/IRTCM CARGO

30 - A

30 - B


LANDING AREA
OPF
OPF
OPF
VAB
PAD
SPACE LAB PROCESSING FACILITY
TELEDYNE BROWN ENGINEERING
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
HOURS

30 - B

30 - C

is accomplished when the payload doors are opened in the OPF. Power and monitoring are required onboard until the specimens are removed.

2.6 GSE AND FACILITY REQUIREMENTS

This section presents the major GSE and facility requirements for processing operations that have been identified as a result of the processing flows. These items are recognized as essential for the successful processing of the cargo.

Any experiment unique GSE will be furnished by the user, with the possible exception of transportation items or other items KSC may agree to furnish upon request. It was originally planned that specific experiment equipment would also be identified. However, there is insufficient information available to be definitive of particular experiments. Some facility requirements were envisaged to support different experiment groups, however.

For the Spacelab/ATL/IRTCM cargo,a support equipment listing of required equipment to meet specific processing requirements and functions was prepared. From this listing, support equipment identification sheets were prepared for servicing equipment and facility items that were new, peculiar,or associated with hazardous operations.

The support equipment listings were separated into facility equipment, identified with a "F" number, and a Spacelab cargo, identified with a "S" number. The "S" identification was further divided into servicing, handling and access, electrical, transportation, and miscellaneous by the addition of a appropriate second letter.

For the Spacelab/ATL/IRTCM cargo,11 items of facility equipment and 66 items of support equipment have been recognized as a result of the processing flows. From this listing, support equipment identification sheets were prepared for 13 items. The title, basic function, and description of these items are shown on these sheets. The support equipment listing for the following Spacelab/ATL/IRTCM equipment categories are included in Appendix D.

- Facility
- Spacelab Electrical

- Spacelab Handling and Access
- Spacelab Tunnel Handling and Access
- Spacelab Servicing
- Spacelab Tunnel Servicing

2.7 PROCESSING HAZARDS SUMMARY

Ten hazard types have been identified with 17 operational events in the Spacelab Normal Base Line Processing Flow. These hazard types, their HMEA number, the frequency with which they occur, and the final hazard categorization after the application of hazard reduction methods are as follows:

Hazard Types	HMEA Number	Frequency of Occurrence	Final Hazard Categorization
GN_2 Purge	H002	1	Controlled
High Pressure GN_2*	H004	5	1 Controlled 4 Catastrophic
Electrical Power	H006	6	Controlled
Lasers	H009	2	Controlled
Freon*	H012	3	Controlled
Pyrotechnics--Armed*	H017	2	Controlled
Radar	H034	2	Controlled
Steam Generator	H035	2	Controlled
High Pressure GO_2*	H036	2	Catastrophic
Microbiological*	H037	3	Controlled

*Continue or carry over to other operations and present the possibility of interface or interaction effects during subsequent operations.

2.7.1 Hazard Mode and Effects Analysis

Functional Event Sheets for the Spacelab Normal Processing Base line flagged each hazardous operation for a hazard analysis. By examining each operational event (where a hazard or hazards had been uncovered) in conjunction with the HMEA of that type of hazard (e.g., laser and electrical), a determination of the initial hazard impact on the payload, cargo, facilities, Orbiter, and personnel was made. The impact whether catastrophic, critical, or controlled and what was affected, such as payload and cargo, was indicated on the Normal Processing Base Line Flow along with the final categorization that shows the result after the application of control measures listed on the HMEA for that hazard type. The HMEA's for the 10 hazard types shown in paragraph 2.7 are located in Appendix E.

2.7.2 Interface Hazards

If the hazard were a "one event only" hazard, it was indicated by a hexagon on the processing flow chart. If the hazard were one that would continue over several operational events, it was indicated by a circle and a line was run from the source event to the terminal event where the hazard was closed out with a hexagon. Events containing more than one hazard may have interface hazards associated with them, and also, events where hazards are continued from previous events operating on or operated on by an event initiated hazard can also have interface hazards. In this manner, the processing flow clearly shows all possible hazard interactions for each operation.

An interface hazard represents a potential accident type that could occur if one hazard source were to go out of control (an accident) and operate on another hazard source causing it to go out of control. In accidents resulting from an interface, the combined effects are often different and/or worse than the singular uncombined effects of either.

In Spacelab/ATL Normal Base Line Processing Flow, two events present interface potential. These are as follows:

- Event 2.03--Interface Connect and Verify

- Event 2.05--Orbiter Integrated Tests

In both of these events, power is applied to make checks and verification of various electrical networks. Inadvertent activation of the laser, radar, or steam generator has the potential of injuring personnel and/or damaging the cargo and the Orbiter.

2.8 SAFETY REQUIREMENTS AND LAUNCH SITE PROTECTION

Identification of the 10 types of hazards associated with the Spacelab Normal Base Line Processing Flow has presented the requirement for providing recommendations and/or preventative measures that could help to alleviate the severity/occurrence of the hazard. The detailed safety, operational and facility requirements for each of these 10 hazards are presented in Appendix E. A summary of the more pertinent requirements that have been established for each of the identified hazards are:

- GN_2 Purge (H002)

  The prevention of personnel injury from asphyxiation can be effected most readily by limiting the access of personnel to areas where purge operations are being conducted, and to provide proper ventilation or self-contained breathing apparatus for those persons that must enter the area. Proper use of restraints or tiedowns and vent/relief capability can help preclude rupture of high pressure vessels and lines, and thereby prevent damage to personnel and equipment caused by whipping of unsecured lines, etc.

- High Pressure GN_2 (H004)

  High pressure testing or checking of tanks/lines/fittings always presents the hazard of a rupture or burst that could result in personnel injury and damage to facilities and equipment. Remote operation or where required, provision for restricted access and appropriate caution and warning procedures can considerably reduce the exposure of personnel to such hazards.

- Electrical Power (H006)

  Probably the single most effective means for preventing electrical shock to personnel is through the use of Ground Fault Interrupter (GFI) devices. The use of proper operational procedures, checklists,and safety interlocks will help prevent the inadvertent creation of associated electrical hazards,such as arcing and high voltage discharge, which can result in fires and damage to equipment.

- Laser (H009)

  A laser checkout facility should be used to limit access to the area during testing, and to provide barriers and curtains to contain the reflected light. Eye shields should be worn at all times during tests with lasers.

- Freon (H012)

  Adequate facility ventilation and avoidance of smoking or open flames in the area where halocarbon vapors may be present should preclude most hazardous conditions to personnel from these materials.

- Pyrotechnics--Armed (H017)

  Before removing shorting caps from Electro Explosive Devices (EED's) and connecting pyrotechnic devices, checks should be made for RF or magnetic fields and for energized electrical connectors. Only essential personnel should be allowed when Class A pyrotechnics are being installed, checked out, and connected.

- Radar (H034)

  Control of this type of electromagnetic radiation is most important to avoid personnel injury and initiation of unprotected pyrotechnic devices. The most obvious and effective measures for controlling this radiation are to provide covers for the equipment (antennas) when not in operation and to provide physical barriers to limit access during operations.

- Steam Generator (H035)

  Safety/operational requirements for operation of the steam generator point out the need to verify the tank integrity before use and to limit access to the area during first checkout.

- High Pressure GO_2 (H036)

  Primary safety/operational requirements for working with high pressure gaseous oxygen in addition to the more obvious hazard of this material in contact with combustible materials such as grease, oils, etc., are the need for limiting access during operations and verification of tank integrity before use.

- Microbiological (H037)

  Safety requirements when working with microbiological specimens necessitate certain precautions for the protection of personnel, such as adherence to proper operational and/or laboratory safety techniques, wearing protective masks, use of hoods, gloved boxes, etc.

2.9 PAYLOAD SAFETY RELATED RECOMMENDED CRITERIA

Identification of the 10 types of hazards associated with the Spacelab Cargo Normal Base Line Processing Flow has also presented the requirement for providing pertinent payload design criteria that could help to reduce the severity or occurrence of the hazard. The detailed criteria set forth for each of these hazards are provided in Appendix E. A brief summary of the more significant criteria emanating from this study are presented below:

- GN_2 Purge (H002)

  No payload design requirements were found to be applicable to this hazard.

- High Pressure GN_2 (H004)

  All high pressure tanks should be designed with pressure relief valves to limit pressure and the tanks should be designed to limit shrapnel in case of a inadvertent rupture or burst. Pressurized flight systems should be connected to the Orbiter vent system to allow venting before returning from Orbit.

- Electrical Power (H006)

  All electrical equipment, connectors, etc. should conform to the provisions of the National Electrical Code and the applicable NASA and MIL Standards. The designs of safety critical switches and controls should be such that they are readily accessible in the event of a major incident.

- Laser (H009)

  Safety related design features for laser operations should include electrical/mechanical interlocks to prevent inadvertent energizing, limits or stops to limit pointing direction, and a C&W system to provide a warning if the beam is out of limits.

- Freon (H012)

  All systems using pressurized gases should include provisions for the relief of overpressure and for the venting of the systems in orbit.

- Pyrotechnics--Armed (H017)

  Ordnance firing circuits must be designed so that after one failure, a second failure will not fire the circuit. The payload design should include the location of the pyrotechnic initiators for easy accessibility when the cargo is in the Orbiter bay. Shielding of all leads from stray RFI is required.

- Radar (H034)

  Design of this equipment should include the incorporation of power/lockout devices in addition to on/off switches to ensure that no single failure can cause inadvertent operation.

- Steam Generator (H035)

  Safety design criteria most pertinent to the steam generator should include the use of a power/lockout device in addition to on/off switches to ensure that no single failure can cause inadvertent operation, and a steam relief valve connected to the Spacelab vent system should be incorporated. The experiment design should include a containment structure.

- High Pressure GO_2 (H036)

  Tanks should be designed with appropriate safety factors, pressure relief devices to limit pressure, and flight article tanks should be designed to limit shrapnel.

- Microbiological (H037)

  The design of biological specimen packaging should include provision for release of a neutralizing agent (a biocide, etc.) in case of specimen release from the test tubes or vials.

3.0 IUS/F2PU/PJP CARGO PROCESSING PLAN

3.1 CARGO DESCRIPTION

The IUS/F_2PU/PJP cargo consists of an expendable hypergolic IUS, a F_2PU, and a PJP. Each element composing this cargo is expendable. The basic mission objective is to transport the PJP to Jupiter to explore its atmosphere structure to a depth of 10 bars.

3.1.1 Pioneer Jupiter Probe

The basic mission objective of the PJP is to determine Jupiter's atmosphere structure and composition to a depth of 10 bars, to determine the location and composition of clouds around Jupiter, and to measure interplanetary environment.

The mission objectives are met with a spin stabilized spacecraft that is composed of two basic units: a bus and an entry probe. The bus with its attached entry probe will fly to Jupiter. The probe will be aimed at Jupiter and released from the bus, which on its flyby will act as a relay to transmit the data the probe is recording to earth.

The PJP configuration is as shown in Figure 9. The bus unit of the PJP contains the following systems:

- Structure (Equipment Compartment, Booms, and Honeycomb Antenna)
- Environmental Control (Passive Louvers and Insulation)
- Guidance, Navigation, and Control (Sun and Star Tracking and Ground RF Command)
- Propulsion (Velocity Control through Thrusters with Hydrazine Propellant)
- Attitude and Spin Control (Thrusters with Hydrazine Propellant)

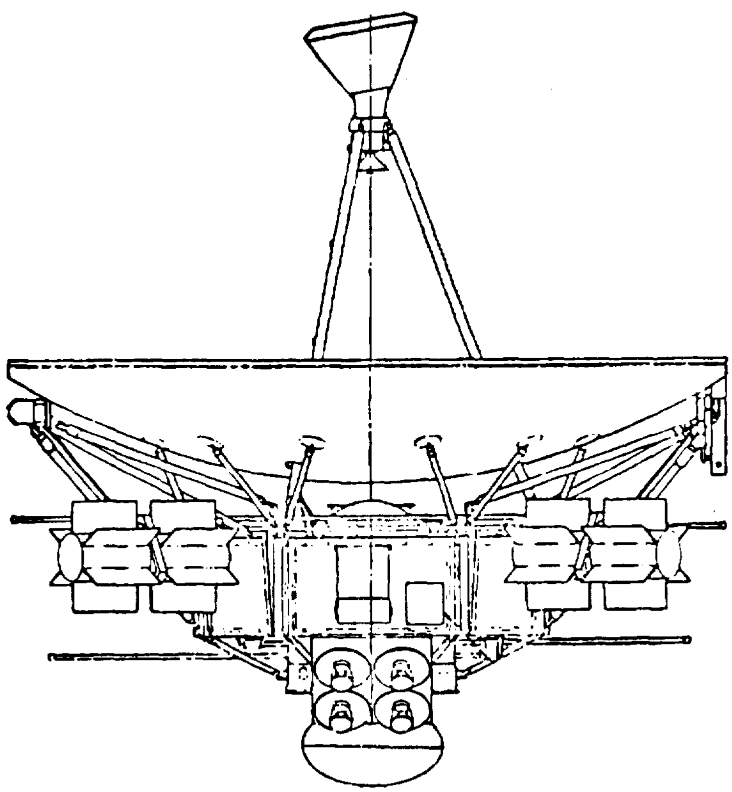


FIGURE 9. PIONEER JUPITER PROBE CONFIGURATION

- Tracking and Command (X&S Band TLM and 400 MHz Probe Relay Link)
- Electrical (RTG Power)
- Experiments
- Separation (Bolt Cutters and Associated Ordnance).

The bus will collect the following type of data:

- Photograph planet cloud surface with its Multispectral Line Scan Camera.
- Planetary atmosphere temperature, pressure, and composition with its IR radiometer, IR spectrometer, and its UV photometer.
- Planetary internal structure and trapped radiation as well as interplanetary/interstellar magnetic field/wind/cosmic rays with its magnetometer, solar wind analyzer,and charge particle detector.
- Meteoroid flux versus size in space and near Jupiter with its 12 penetration panels.

The Entry Probe Systems are:

- Structures (Equipment Compartment)
- Telemetry
- Experiments

  --Atmospheric composition with its Quadropole Neutral Mass Spectrometer

  --Atmospheric temperature with its thermocouple temperature gage

  --Atmospheric pressure with its transducer pressure gage

-- Atmospheric density with its 3-axis accelerometer

-- Cloud density and altitude with its light source nephelometer detector.

3.1.1.1 Summary of Hazardous Materials/Systems

The general hazards associated with the PJP are as follows:

- Electrical
- Radiological--RTG's and Radioisotope Heater Units (RHU's)
- Hypergolic--Hydrazine
- Fire/Explosive--Pyrotechnics, Batteries
- High Pressure--GN_2 and GHe
- High Temperature--RTG's
- RF (Communications).

3.1.2 Fluorine Propulsion Unit

This conceptual propulsion unit is a basic blowdown type and is composed of a closed loop LN_2 cooled fluorine oxidizer system with mono-methyl hydrazine as its fuel element. The propellant capacity is conceived to be between 1,500 and 3,000 lb. The ratio of propellants is approximately 2/3 F_2 and 1/3 N_2H_4, with tank operating pressure at approximately 350 psig. The F_2 tank is insulated with Polyurethane Foam and has an internal LN_2 cooling coil system. The LN_2 cooling supply can be removed for 3 to 6 hr during normal operations without the loaded F_2 tank becoming overpressurized. The F_2PU receives its commands through the PJP, thus allowing a very simple and straight forward design. The design configuration of this fluorine stage has not been fully developed and is based on a preliminary concept only.

This propulsion unit contains the following major systems:

- A closed loop F_2 oxidizer system with fill and vent capabilities

- A LN_2 cooling system for the F_2 tank
- A mono-methyl hydrazine fuel system with fill and drain capabilities
- An engine system
- A spin/despin and separation system
- A structure system

3.1.2.1 Summary of Hazardous Materials/Systems

The general hazards associated with this propulsion unit are:

- Hypergolic--Mono-Methyl Hydrazine
- Hypergolic/Cryogenic--Fluorine
- High Pressure--GN_2, GHe
- Fire/Explosive--Pyrotechnics
- Electrical
- Cryogenic--LN_2 Cooling

3.1.3 Interim Upper Stage

The IUS is a three-axis stabilized stage with guidance using storable propellants and pressure-fed engines designed to deliver a 5,000 lb payload from low earth orbit to synchronous orbit and to escape velocity. The expendable IUS is a 120-in. diam 230-in. long stage that has a utility life limit of 8 hr. The IUS/Payload mounted in the Orbiter cargo bay rests in a cradle that is attached to four Orbiter mount fittings. The IUS has an umbilical connection to the cradle that is separated before the Orbiter Remote Manipulating System (RMS) lifts the IUS/payload free of the cradle, out of the cargo bay, to a release point above the Orbiter.

The IUS configuration is shown in Figure 10. A general description of the IUS systems follows:

- Attitude Control System (ACS): Monopropellant hydrazine stored under helium pressure in spherical tanks.

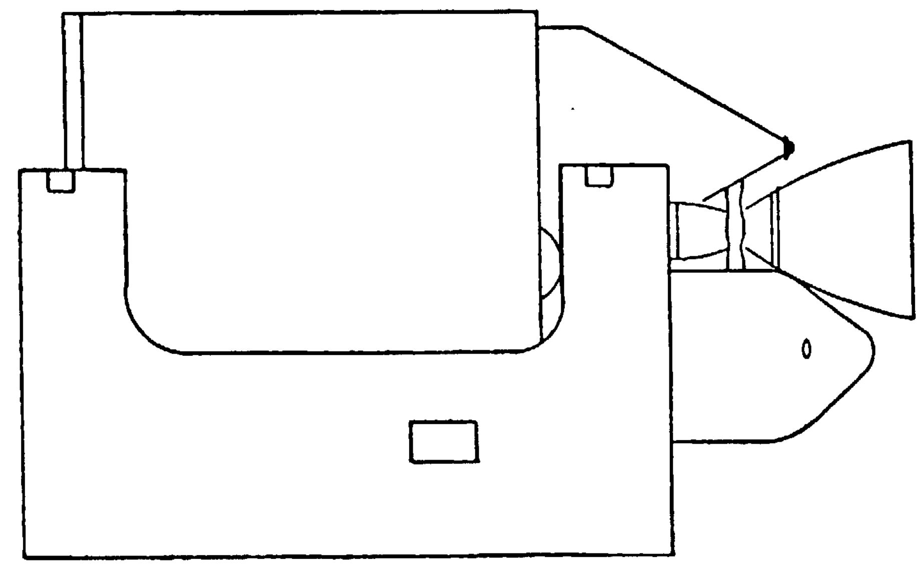


FIGURE 10. INTERIM UPPER STAGE CONFIGURATION

- Electrical Power System (EPS): Battery with vent operates with GH_2 under normal operation and produces KOH during failure mode.

- IUS Main Propulsion System (MPS): Main propulsion system provides 16,000 lb maximum thrust. The main propellant, UDMH/N_2H_4 and N_2O_4 are pressurized from the helium pressurization system.

Other systems to be checked out during ground processing include instrumentation, communication, data management, guidance, navigation, and control system.

3.1.3.1 Summary of Hazardous Materials/Systems

The IUS contains the following general hazards:

- N_2O_4 Oxidizer
- N_2H_4 and UDMH/N_2H_4
- Batteries
- GN_2 and Helium
- Electrical
- RF--Communications.

3.2 PROCESSING SCENARIO

The IUS/F_2PU/PJP processing scenario shows a likely sequence of operations essential to process this cargo for the prelaunch and launch phases of its operational cycle. Buildings and areas have been identified that most reasonably accommodate the major operations required to process the individual elements (IUS/F_2PU/PJP) of this cargo as well as those for the combined cargo.

Throughout the analysis there has been a continuous endeavor to evolve the best practical sequence of activities for a reasonably safe and timely set of prelaunch and launch processing plans. This has been reflected in our selection of the relative placement of activities with respect to one another and the location where performed.

The scenario (Figure 11) covers the full cycle of operations as follows:

- The PJP is off-loaded at KSC airstrip and moved from the airstrip to the AO Hanger where it is inspected, shipped loose parts assemblied, functionally tested, and leak checked.

- The F_2PU and IUS are off-loaded at KSC airstrip and transported to SAEF #1 where they are inspected, shipped loose parts assembled, functionally tested, and leak checked. The IUS APS is loaded at SAEF #1 where in the case of F_2PU and PJP, the APS is loaded and test fired in Propellant Lab 60A.

- After APS test firing, the F_2PU is transferred to the fluorine facility where fluorine is loaded and the system stabilized. The F_2PU and PJP are then moved to SAEF #1 where they are mated with the IUS.

- The mated cargo is moved to the pad and lifted from the transporter into the PCR.

- The cargo is then loaded into the Orbiter bay and Orbiter/cargo interfaces are mated and verified. The RTG's that were off-loaded, received, inspected, and tested at the SAEF #1 area in Building M7-1472 are now installed in the cargo and tested. The Orbiter bay is closed, PCR is retracted, and countdown is initiated.

In addition to the normal processing scenario discussed, three contingency situations are presented. Two contingency situations at the pad are shown:

- Backout Operations

- Vertical Changeout at Pad

The third contingency, Mission Abort, is shown as an alternative to the normal in-flight operations.

The flow plans for these contingency situations are included in Volume 4.

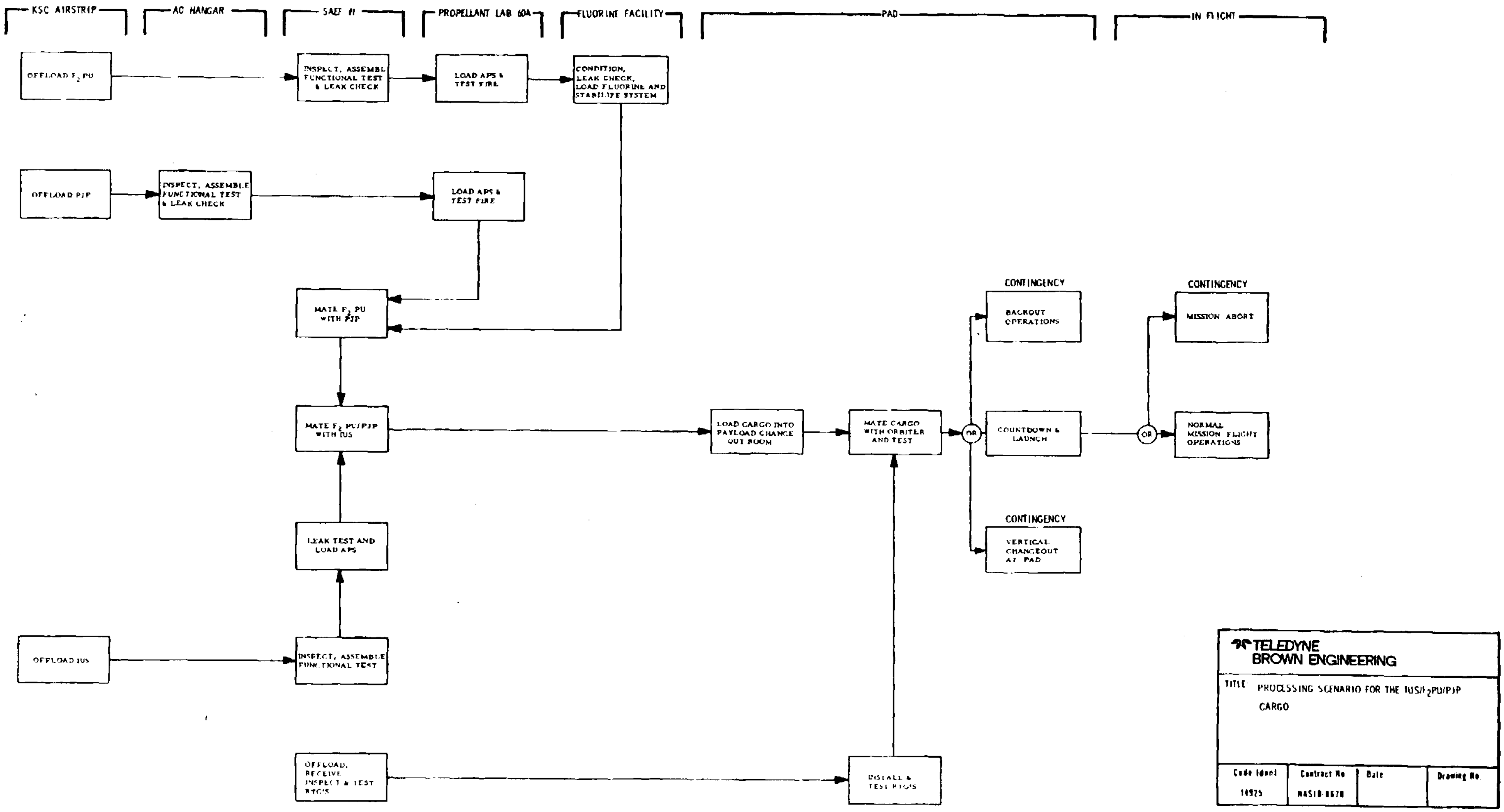


FIGURE 11. PROCESSING SCENARIO FOR IUS/F_2PU/PJP CARGO

3.3 PROCESSING FLOWS

This section presents the IUS/F_2PU/PJP Launch Site Processing Flow Plans that were derived during this study. These flow plans identify each major operation necessary to prepare the payload for flight and acknowledge the payload hazardous parameters that exist during these operations.

A top-level flow was developed to show individual payload operations, cargo operations, and launch operations. This top-level flow is essentially an index of operations at different areas and was expanded into a second level flow that is a detailed operational sequence for each cargo. Development of this flow was an interative process and through a series of iterative tradeoffs, the normal base line processing flow plans were formed.

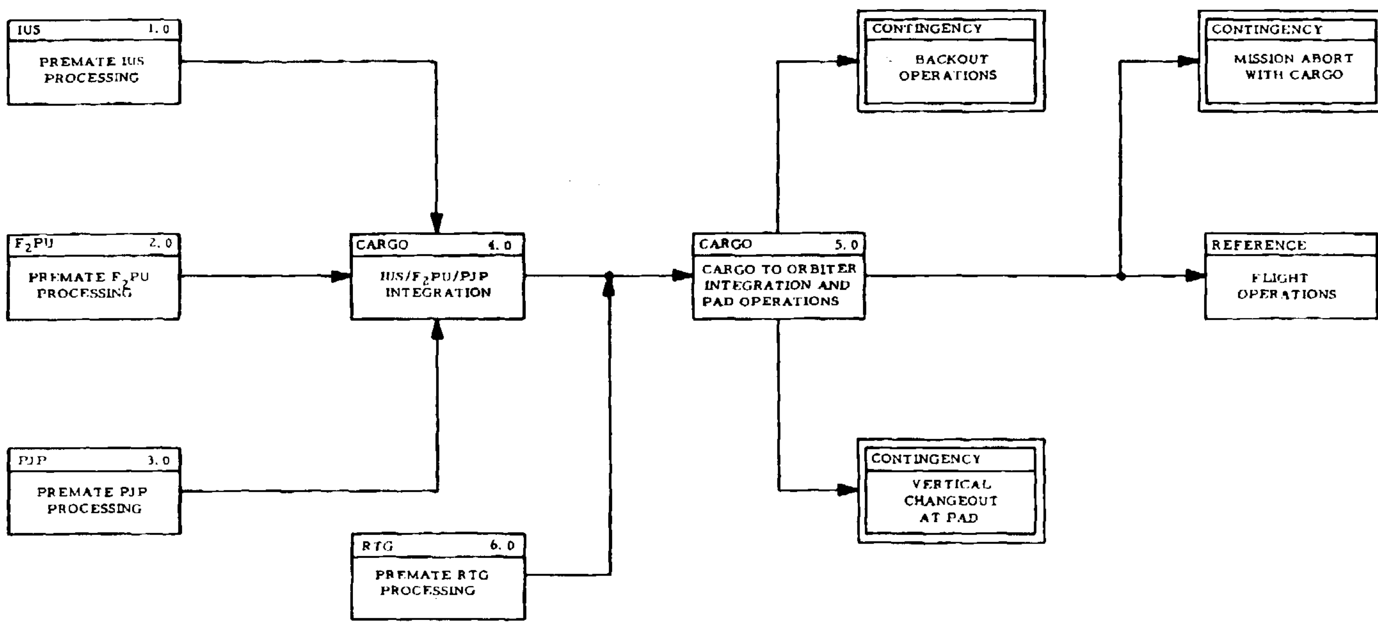
3.3.1 Top-Level

While the scenario for the IUS/F_2PU/PJP cargo shows basic and essential operations to enable its processing, a slightly different format was established to be used as a top-level functional flow. The top level IUS/F_2PU/PJP Launch Site Processing Flow Plan is shown in Figure 12. This figure shows six major areas that provide convenient breakouts for the second level functional flows and have been addressed at the first level. The six major areas are:

- 1.0 Premate IUS Processing
- 2.0 Premate F_2PU Processing
- 3.0 Premate PJP Processing
- 4.0 IUS/F_2PU/PJP Integration
- 5.0 Cargo to Orbiter Integration and Pad Operations
- 6.0 Premate RTG Processing

3.3.2 Normal Base Line

The IUS/F_2PU/PJP second level functional flow diagram referred to as the normal base line processing flow is an expansion of the first level with sufficient details to enable a hazards analysis to be performed from the second level functional event sheets.



TELEDYNE BROWN ENGINEERING

TITLE: TOP LEVEL PROCESSING FLOW FOR THE IUS/F_2PU/PJP CARGO

Code Ident	Contract No.	Date	Drawing No.
14925	NAS10-8676		

FIGURE 12. TOP LEVEL PROCESSING FLOW FOR THE IUS/F_2PU/PJP CARGO

The Normal Base Line Processing Flow (Figure 13) represents the output of an iterative process. Many feasible options in sequencing certain activities were examined to weigh their respective advantages and disadvantages, considering the parameters of safety, time, and facilities. Through this process some hazardous operations were either eliminated, reduced, or replaced by less hazardous ones, or the sequence and/or locations changed so as to have a lesser impact. This process led to the evolvement of the normal base line processing flow. For each individual item on these flows, a functional event sheet was prepared to define the operation to a level necessary to identify all hazards, estimate operations times, and identify GSE.

Certain basic assumptions and criteria were established during the formulation of the normal base line processing flows. These are discussed as follows:

- SAEF #1, or another Tug processing facility, would handle processing of the Tug, IUS, and cargo mating operations.
- The Shuttle payload flow at KSC would require utilization of all available facilities. Propellant Lab 60A would be used for some off-pad payload propellant loading, and APS propellants for some payloads would be loaded in this facility.
- Upper stages and payload APS systems would be test fired to verify operations and wet system seals before launch.
- Propellant Lab 60A will not handle a IUS/F_2PU/PJP cargo or a Tug/SEPS/SEOS cargo because of size limitations.
- The Tug and IUS and their cargoes would be processed in the vertical position.
- The Tug and the IUS and their cargoes would be mated into the Orbiter at the pad through the payload changeout room.

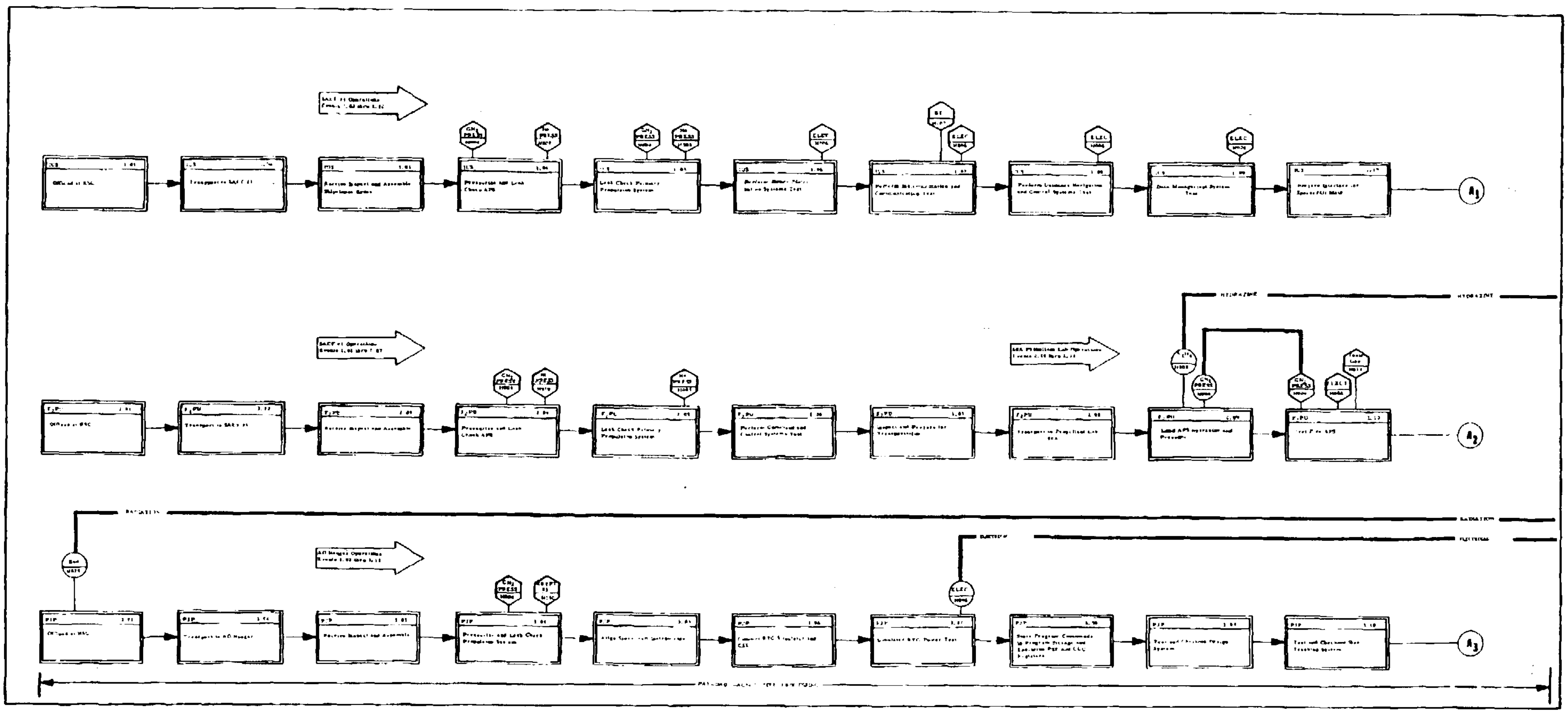


FIGURE 13. NORMAL BASE LINE PROCESSING FLOW FOR THE IUS/F_2PU/PJP CARGO (Sheet 1 of 5)

51 - A

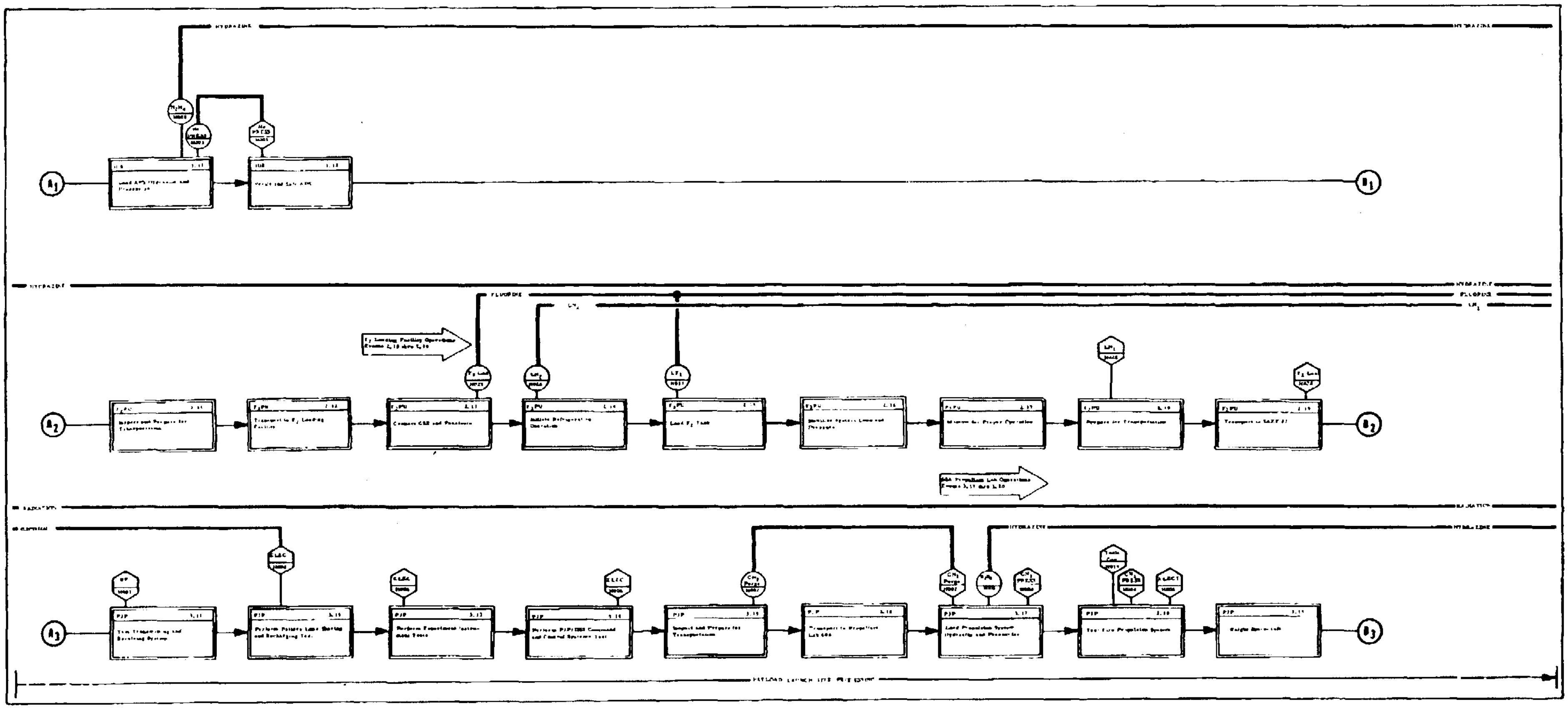


FIGURE 13. NORMAL BASE LINE PROCESSING FLOW FOR THE IUS/F_2PU/PJP CARGO (Sheet 2 of 5)

52 A

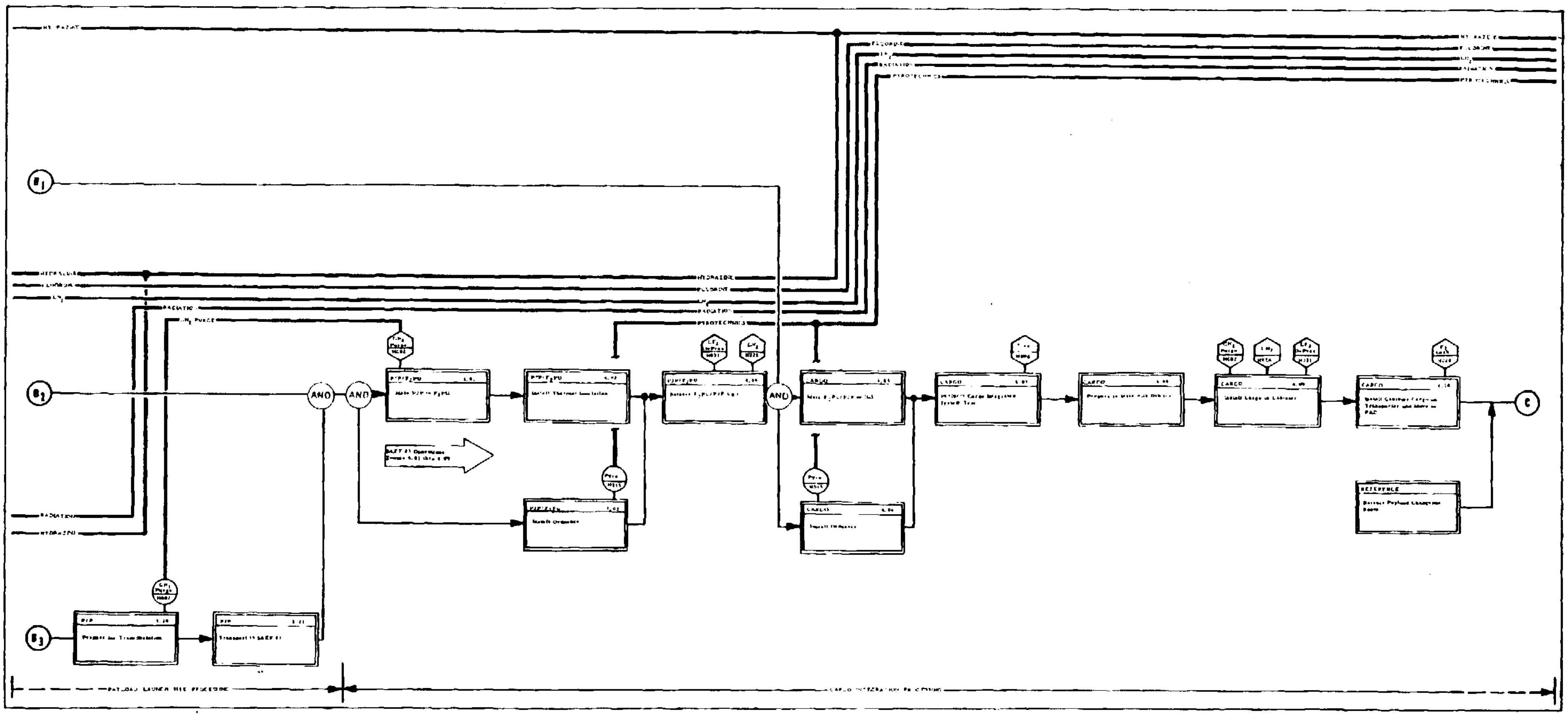


FIGURE 13. NORMAL BASE LINE PROCESSING FLOW FOR THE IUS/F_2PU/PJP CARGO (Sheet 3 of 5)

53 - A

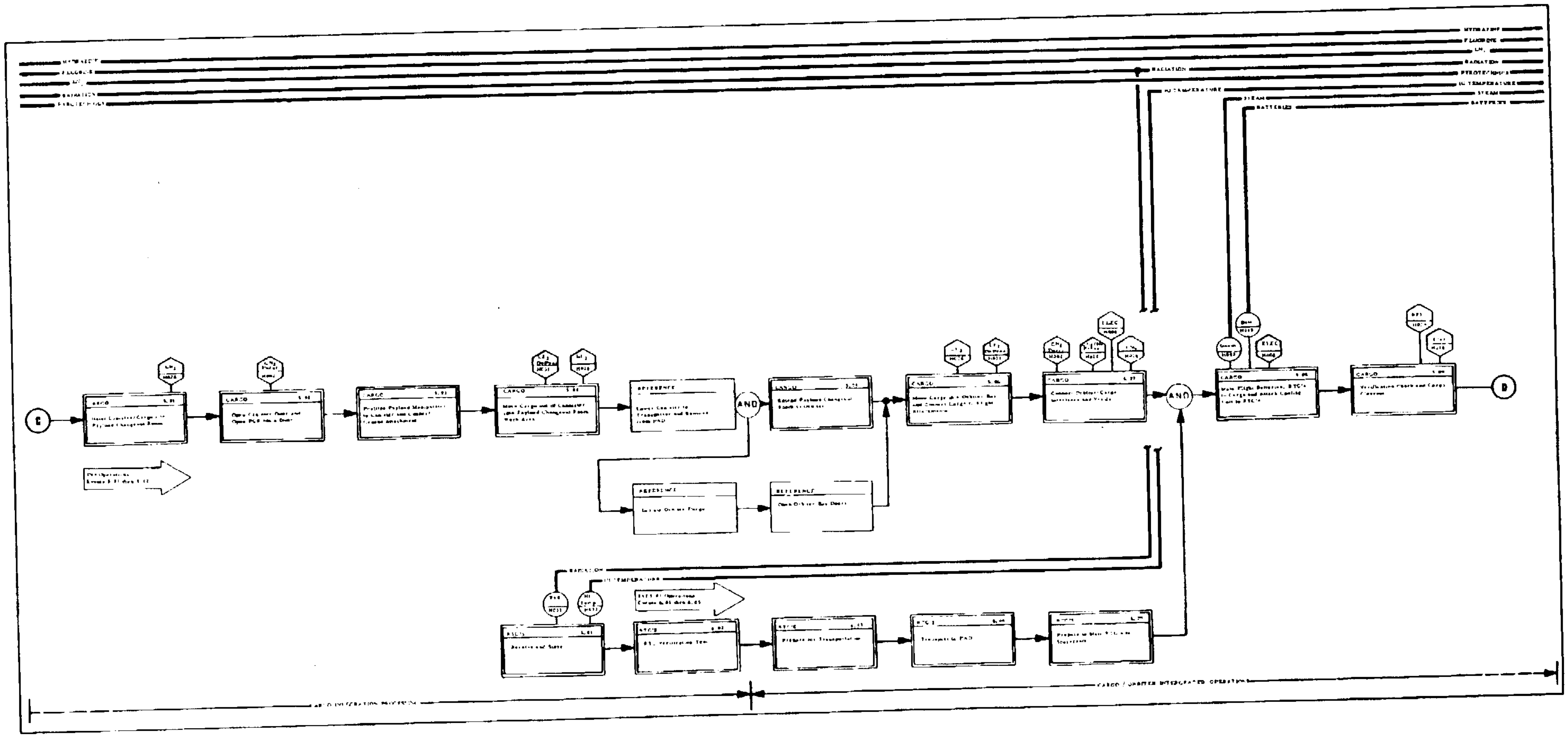


FIGURE 13. NORMAL BASE LINE PROCESSING FLOW FOR THE IUS/F_2PU/PJP CARGO (Sheet 4 of 5)

54-A

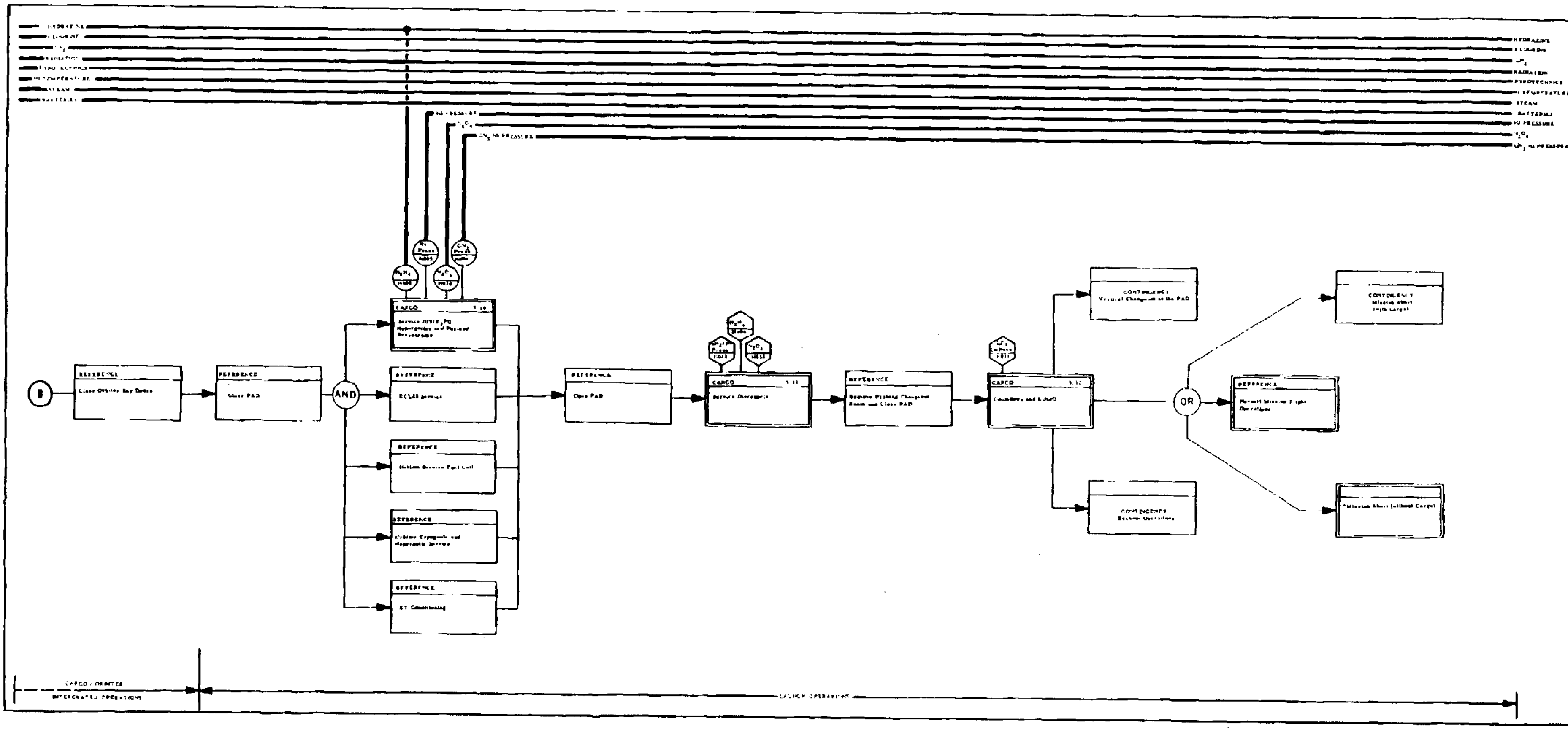


FIGURE 13. NORMAL BASE LINE PROCESSING FLOW FOR THE IUS/F_2PU/PJP CARGO (Sheet 5 of 5)

55-A

3.3.3 Options to Normal Base Line

3.3.3.1 Fluorine Loading

Many options are available for loading the fluorine oxidizer in the F_2PU payload. The first option studied was loading at the pad in the Orbiter bay. An alternate pad loading option that had been considered by other fluorine studies was loading in the payload changeout room. Both of the options were investigated from a time and hazards standpoint and were found to be impractical.

The primary problem with fluorine loading operations is the severe consequences of a spill or leak that is most likely to occur during propellant transfer. Fluorine reacts with most materials and is extremely corrosive to many metals. Also, the consequences of a major spill would have a pronounced effect on the environment and pose a hazard to personnel in the area and to the general public. The hazards of fluorine operations alone are sufficient to reject pad loading, but the time required to passivate, load, and thermally balance the LF_2 tank is approximately 31 hr. This time prohibits loading in the cargo bay regardless of hazards and would tie up and restrict access to the pad area for 31 hr if the payload changeout room were used for loading.

For these reasons, it was determined that all fluorine loading operations should be performed off-line in a remotely located facility designed especially for controlling hazardous fluorine operations.

The next fluorine processing option to be considered is where in the processing cycle the fluorine is to be loaded. The obvious choice is to perform all cargo integration functions and load the fluorine just before the cargo is ready for transport to the payload changeout room. This option minimizes the handling and exposure of personnel to the fluorine stage. However, considering the extremely corrosive effect of F_2 vapors on electronic and electrical equipment and that the highest likelihood of F_2 vapors being present is during the F_2 passivation and loading it was concluded that IUS and PJP critical electronics damage would be likely using this approach. Also, loading F_2 after integrating the payloads would result in the cargo having to repeat most of the testing performed during earlier payload and cargo testing. This repeat testing would require as much personnel exposure to F_2 as the approach selected and almost double the required cargo testing. If a circuit were effected by F_2 vapors during loading, to repair or replace the element would also prolong the processing time and increase personnel exposure to F_2. However, after a F_2 system is properly passivated, loaded, and stabilized, the likelihood of F_2 vapors leaking is much smaller. These considerations resulted in our recommending loading of the F_2 prior to integration with the other payloads. This recommendation is based on the assumption that the LF_2 tank cooling concept can maintain the cryogenic fluorine pressure near atmospheric pressure. This may require a pressurization system for flight pressurization of the LF_2 system.

3.4 FUNCTIONAL EVENTS DESCRIPTION

The purpose of these functional event sheets is to describe each IUS/F_2PU/PJP processing operation, give the sequence of events required to complete the operation, and estimate the time required. For each event in the operation, potential hazardous conditions are noted and cross-referenced to a hazards analysis. GSE and facilities associated with this operation are also shown. Hazardous materials or systems loaded or activated in a previous operation are indicated by hazard category.

The operation sequence portion of these functional event sheets defines each of the IUS/F_2PU/PJP normal base line processing flow operations to a level necessary to identify all hazards, estimate operations times, and identify GSE. Seventy-nine normal base line processing flow operations were identified for the IUS/F_2PU/PJP cargo. Hazardous conditions were identified with 46 of these 79 operations.
79 operations.

The functional event sheets for the IUS/F_2PU/PJP normal base line processing flow operations are in Appendix B.

3.5 WATERFALL/TIME LINE

The IUS/F_2PU/PJP Waterfall/Time line provides a visual guide to the series and parallel relationship of the various processing flow operations and are time-phased to show the time allocation for each operation. The processing flow operations were base lined early in this study in accordance with KSC Shuttle/Tug Turnaround Allocation, December 16, 1974. These time lines were not updated by subsequent changes or modifications to the operational allocations since these changes were not detrimental to the results of this study. The numbers and titles appearing on the events refer to the IUS/F_2PU/PJP functional flow diagram item numbers.

3.5.1 Normal Base Line

The normal base line processing flow time line is illustrated in Figure 14. This time line shows the complete flow of each element of this cargo from arrival at KSC to launch. This time line includes approximately 55 hr prior to Orbiter landing for off-line receipt, inspection, and assembly of the PJP. The IUS, PJP, and F_2PU are individually followed (through SAEF #1, AO Hanger, F_2 loading facility, and Propellant Lab 60A) until they are mated into an integrated cargo at approximately 52 hr prior to launch. The RTG's for this cargo are received and tested off-line and then mated to spacecraft on the pad. The pad time for this cargo is 30 hr. The Shuttle events for this time line are referenced but not identified.

Fluorine loading for the F_2PU elements is off-line because the loading and thermal balancing is very hazardous and loading off-line reduces the Orbiter, PJP, and IUS exposure to a hazardous operation.

The decision to perform the F_2 loading off-line was based in part on the following considerations:

- First, a good safety criterion is to isolate hazardous operations as much as practical, especially when the type of operation is not commonly performed and the experience level is low. Of particular concern here is the escape of extremely corrosive F_2 vapors and the damage it could cause to the Orbiter, IUS, or PJP electrical and electronic components.

- Second, the 31 hr required to passivate, load, stabilize, and monitor the system integrity would have an adverse impact on the Orbiter time line if performed at the pad.

3.6 GSE AND FACILITY REQUIREMENTS

This section presents the major GSE and facility requirements for processing operations that have been identified as a result of the processing flows. These items are recognized as essential for the successful processing of the cargo.

Any experiment unique GSE will be furnished by the user, with the possible exception of transportation items or other items KSC may agree to furnish upon request. It was originally planned that specific experiment equipment would also be identified. However, there is

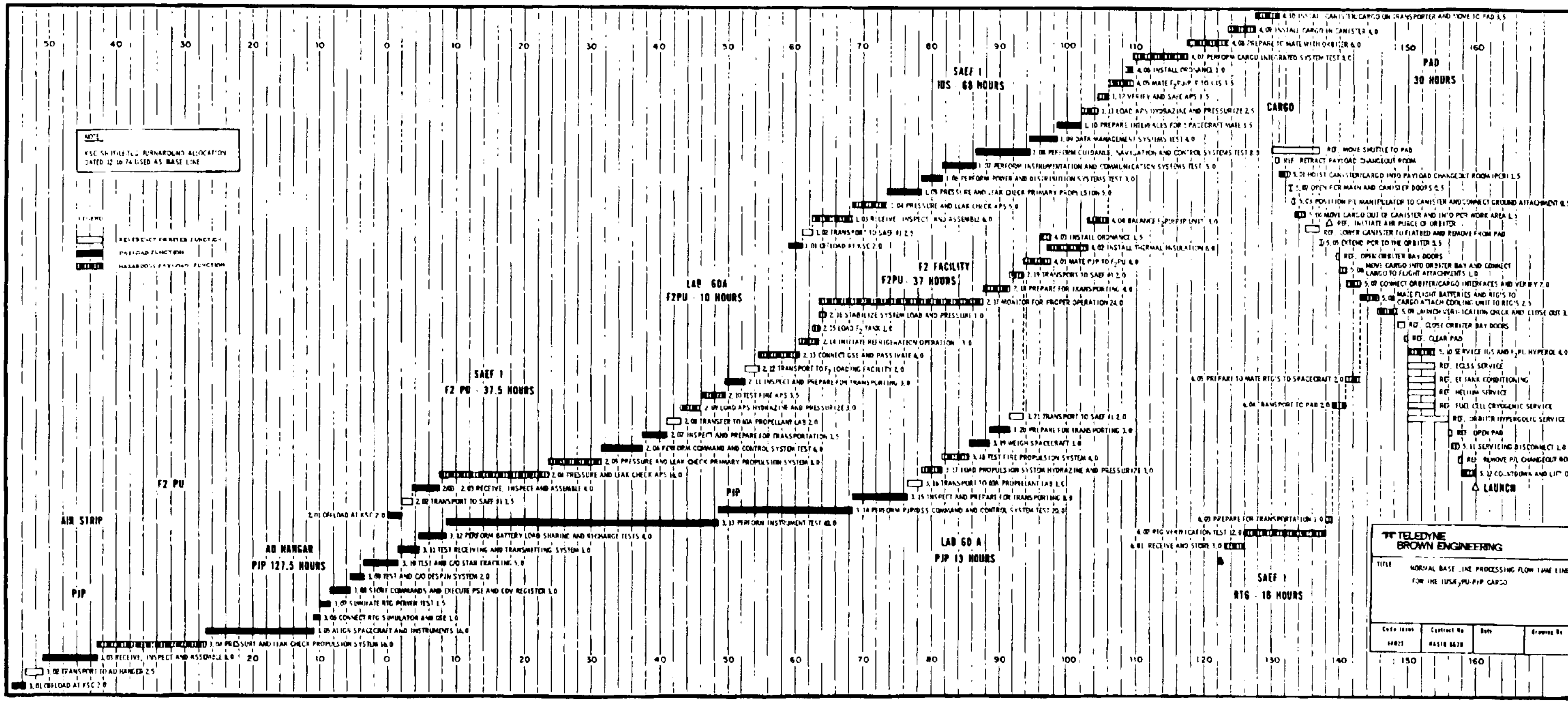


FIGURE 14. NORMAL BASE LINE PROCESSING FLOW TIME LINE FOR THE IUS/F_2PU/PJP CARGO

59-A

59-B

insufficient information available to be definitive of particular experiments. Some facility requirements were envisaged to support different experiment groups, however.

For the IUS/F_2PU/PJP cargo, a support equipment listing of required equipment to meet specific processing requirements and functions was prepared. From this listing, support equipment identification sheets were prepared for servicing equipment and facility items that were new, peculiar, or associated with hazardous operations.

The support equipment listings were separated into facility equipment, identified with a "F" number, and a powered cargo, identified with a "P" number. The "P" identification was further divided into servicing, handling and access, electrical, transportation, and miscellaneous by the addition of a appropriate second letter.

For the IUS/F_2PU/PJP cargo, 23 items of facility equipment and approximately 134 items of support equipment have been recognized as a result of the processing flows. From this listing, support equipment identification sheets were prepared for some items. The title, basic function, and description of these items are shown on these sheets. The support equipment listing for the following IUS/F_2PU/PJP equipment categories are included in Appendix D.

- Facility
- Electrical
- Handling and Access
- Servicing
- Transportation
- Miscellaneous.

3.7 PROCESSING HAZARDS SUMMARY

Twenty-one hazards types have been identified with 46 processing operations in the IUS/F_2PU/PJP normal base line processing flow. These hazard types, their reference HMEA number, the frequency with which they occur, and the final hazard categorization after application of hazard reduction methods are as follows:

Hazard Types	HMEA Number	Frequency of Occurrence	Final Hazard Categorization
GN_2 Purge*	H002	6	Controlled
GN_2 High Pressure*	H004	8	Catastrophic
He High Pressure*	H005	6	Catastrophic
Electrical*	H006	13	Controlled
RF	H007	2	Controlled
N_2H_4 *	H008	2	Critical
Toxic Gas	H014	2	Critical
Pyrotechnics--Safed*	H015	2	Controlled
Pyrotechnics--Armed *	H017	1	Controlled
Battery*	H019	1	Controlled
GN_2/He Pressurization	H022	1	Critical
GF_2	H025	1	Critical
LN_2*	H026	5	Controlled
LF_2*	H028	2	2 Critical
Radiological*	H029	1	Controlled
Krypton 85	H030	2	Controlled
LF_2 Overpressure	H031	5	4 Critical and 1 Catastrophic
High Temperature*	H032	1	Controlled
Radiological*	H033	1	Controlled
RF	H034	1	Controlled
N_2O_4*	H038	2	1 Controlled and 1 Critical

* Also, carry over to other operations and present the possibility of interface or interaction effects during subsequent operations.

3.7.1 Hazard Mode and Effects Analysis

Functional Event Sheets for the IUS/F_2PU/PJP Normal Processing Base Line flagged each hazardous operation for a hazard analysis. By examining each operational event (where a hazard or hazards had been uncovered) in conjunction with the HMEA of that type of hazard (e.g., laser and electrical), a determination of the initial hazard impact on the payload, cargo, facilities, Orbiter, and personnel was made. The impact whether catastrophic, critical, or controlled and what was affected, such as payload and cargo, was indicated on the Normal Processing Base Line Flow along with the final categorization that shows the result after the application of control measures listed on the HMEA for that hazard type. The HMEA's for the 21 hazard types are located in Appendix E.

3.7.2 Interface Hazards

On the Normal Base Line Flow, if a hazard were a "one event only" hazard, it was indicated by a hexagon. If the hazard were one that would continue over several operational events, it was indicated by a circle and a line was run from the source event to the terminal events where the hazard was closed out with another circle. Events containing more than one hazard may have interface hazards associated with them, and also, events where hazards are continued from previous events operating on or operated on by an event initiated hazard can also have interface hazards. In this manner, all possible interaction possibilities from all hazard sources are clearly indicated for each operation.

An interface hazard represents a potential accident type that could occur if one hazard source were to go out of control (an accident) and operate on another hazard source causing it to go out of control. In accidents resulting from an interface, the combined effects are often different and/or worse than the singular umcombined effects of either.

In the IUS/F_2PU/PJP Normal Base Line Processing Flow, several events present potential interface hazards. Examples of the major hazards are:

- Leakage of fluorine can cause critical electronics/electrical circuits to malfunction because of the corrosiveness of fluoride. This effect could cause critical and catastrophic failures of the cargo, payload, or Orbiter.

- A fluorine leak into the fluorine tank heat exchanger could result in release of toxic F_2 vapors through the LN_2 cooling system vent.

- Water leakage from the RTG cooling system could react violently with a fluorine leak after installation in the Orbiter.

- Unfavorable weather conditions during transport of the F_2PU at the launch site could be a catastrophic hazard if a fluorine leak or spill occurs.

Other interface hazards include inadvertent power application to the pyrotechnic devices or stray RFI could result in an explosion or fire.

The F_2PU contains both LF_2 and N_2H_4 after loading the LF_2 tank. The presence of these hypergolic materials through subsequent processing operations is a serious interaction possibility. With LF_2 as the oxidizer, a fire or explosion would be a certainty if the two were accidently mixed. The likelihood of leakage is reduced by applying only a blanket pressure to the APS's and LF_2 tank until the cargo is ready to deploy from the Orbiter in space.

3.8 SAFETY REQUIREMENTS AND LAUNCH SITE PROTECTION

Identification of the 21 types of hazards associated with the IUS cargo normal base line processing flows has presented the requirement for providing recommendations and/or preventative measures that could help to alleviate the severity/occurrence of the hazard. The detailed safety operational and facility recommendations for each of these hazards is presented in Appendix E. A summary of the more pertinent requirements is as follows:

- GN_2 Purge (H002)

Personnel injury from asphyxiation can be prevented most readily by limiting the access of personnel to areas where purge operations are being conducted, and providing proper ventilation or self-contained breathing apparatus for those persons that must enter the area. Proper use of restraints or tiedowns and vent/relief capability can help preclude rupture of high pressure vessels and lines, and thereby prevent damage to personnel and equipment caused by whipping of unsecured lines, etc.

- High Pressure GN_2 (H004) and High Pressure GHe (H005)

Testing or checking of tanks/lines/fittings always presents the hazard of a rupture or burst that could result in personnel injury and damage to facilities and equipment. Remote operation or, where required, provision for restricted access, and appropriate caution and warning procedures can considerably reduce the exposure of personnel to such hazards.

- Electrical Power (H006)

Probably the single most effective means for preventing electrical shock to personnel is through the use of GFI devices. The use of proper operational procedures, checklists, and safety interlocks will help prevent the inadvertent creation of associated electrical hazards, such as arcing and high voltage discharge that can result in fires and damage to equipment.

- RF Emissions (H007)

The wearing of RF monitors by operating personnel can effectively limit their exposure to such harmful radiation. All RF generating equipment should be turned off before performing hazardous operations, such as connecting pyrotechnics devices.

- Hydrazine and its Methyl Derivatives (H008)

The obvious requirements of wearing protective clothing, masks and gloves and having safety showers and eye wash fountains readily accessible will in most cases preclude an accidental spill having a marked effect on personnel. Modifications to the SAEF #1 facility to include a water flush system and a fresh air purge may be required for loading and testing the APS safely.

- APS Thruster Firing--Toxic Gas (H014)

Test firing of these thrusters could generate toxic products such as ammonia and hydrogen, or through malfunction could create a spill of hydrazine. Adequate ventilation and the use of personnel protective equipment should preclude any hazard to personnel from this operation.

- Pyrotechnics--Safed (H015)

The inadvertent activation of ordnance devices can be precluded by the following proper procedures, such as using spark proof tools, use of shorting caps, and handling and storing explosives only in designated facilities.

- Pyrotechnics--Armed (H017)

Before removing shorting caps from EED's and connecting pyrotechnic devices, checks should be made for RF or magnetic fields and for energized electrical connectors.

- Batteries (H019)

Care must be exercised in handling batteries to prevent arcing shoots and to prevent electrolytic spills. The use of nonsparking tools and wearing of protective clothing and goggles should serve to alleviate most of their hazards.

- High Pressure GN_2/GHe (H022)

All operations involving the test, checkout, and operation of high pressure systems should be done remotely when possible, i. e., limiting access and number of operating personnel. All GSE servicers should be vented and safed before disconnecting.

- GF_2 (H025)

A fluorine facility that is dedicated to fluorine loading only is required because of the highly reactive nature of fluorine. Protective clothing and breathing systems are required for personnel working around fluorine. Passivation of the F_2 tanks and transfer lines is required by a special procedure because of the highly reactive nature of fluorine.

- LN_2 (H026)

Piping and tanks should be cold shock tested and leak checked; relief valves should be included in LN_2 dewar systems; LN_2 must be vented outside when located in the Tug Processing Facility; personnel working around LN_2 must abide by KSC safety requirements for cryogenics.

- LF_2 (H028)

A special transporter designed to control LF_2 temperatures and safely contain leaks during transit is required. The loaded F_2PU shall be moved only when weather conditions are favorable and will not aggravate the impact of a spill or leak. Also, only essential and trained personnel with proper protective clothing and safety devices should be allowed where fluorine operations are performed. A F_2 disposal unit is required at the F_2 facility, SAEF #1, and at the pad if emergency venting is necessary.

- Radiological (H029)

Proper radiation shielding will be required to protect personnel and equipment. Occupancy time in "radiation areas" should be limited to that time required to properly perform assigned tasks, and all personnel entering radiation controlled areas shall wear a beta-gamma-neutron sensitive dosimeter. Before RTG's are installed on a spacecraft, work shall not proceed until appropriate health physics measurements have been completed and safe levels of exposure are verified. Maximum distances between personnel and the radiation source (RTG's) shall be maintained through use of proper handling devices. All radiation areas shall be conspicuously posted.

- Krypton 85 (H030)

Krypton 85 is used as a tracer gas for pressure testing systems that have extremely low allowable leak rates. Tests should be performed by personnel trained in handling and testing with a radioactive gas. All personnel will be required to wear beta-gamma film badges.

- LF_2 Overpressure (H031)

The fluorine loading facility shall be used for emergency disposal of fluorine when time allows. However, a portable fluorine disposal unit should also be provided at SAEF #1 and at the pad in the event emergency on site venting is required. Other safety and protective actions include maintaining an adequate supply of LN_2 for cooling at all times, providing a backup cooling system for emergencies, and providing F_2 sensors at all processing locations and in the Orbiter bay. All personnel involved in the operations with the fluorinated oxidizer unit should be trained and certified for fluorine operations. Emergency or contingency actions should be developed and practiced for all possible accident situations.

- High Temperature (H032)

Personnel should wear protective garments, gloves, etc., at all times when working with sources of high temperature. All combustible materials must be removed from the immediate area before the heater is energized.

- Radiological (H033)

Special storage and handling equipment are required for RTG's to prevent exposure or direct contact by personnel with radiation sources. Special guards and shields and radiological warning devices are required during storage and handling. KSC Radiation Protection Handbands KHB 1860. 1/1S shall be followed.

- RF (H034)

Control of this type of electromagnetic radiation is most important to avoid personnel injury and initiation of unprotected pyrotechnic devices. The most obvious and effective measures for controlling this radiation is to provide covers for the equipment (antennas) when not in operation and to provide physical barriers to limit access during operations.

- Nitrogen Tetroxide--N_2O_4 (H038)

Zero leakage service disconnects and protective clothing for operating personnel are required to prevent exposure of operations personnel to toxic vapors. N_2O_4 gas detectors are required for the Orbiter bay. Loading operations will be in accordance with the KSC loading procedure for N_2O_4 and mutually reactive propellants will not be loaded at the same time. In the event that spills occur, they shall be cleaned up immediately or washed down with water.

3.9 PAYLOAD SAFETY RELATED RECOMMENDED CRITERIA

Identification of the 21 types of hazards associated with the IUS cargo normal base line processing flow has also presented the requirement for providing pertinent payload design criteria that could help to reduce the severity or occurrence of the hazard. The detailed criteria set forth for each of these hazards are provided in Appendix E. A brief summary of the more significant criteria emanating from this study is presented below:

- GN_2 Purge (H002)

Payload GN_2 purge outlets should be located so that the GN_2 can be vented outside the Orbiter bay.

- High Pressure GN_2 (H004) and He (H005)

All high pressure tanks should be designed with pressure relief valves to limit pressure and the tanks should be designed to limit shrapnel in case of a inadvertent rupture or burst. Pressurized flight systems should be connected to the Orbiter vent system to allow venting before returning from orbit.

- Electrical Power (H006)

All electrical equipment, connectors, etc., should conform to the provisions of the National Electrical Code and the applicable NASA and MIL Standards. The designs of safety critical switches and controls should be such that they are readily accessible in the event of a major incident.

- RF Emissions (H007)

Equipment that generates EMI radiation should be designed to contain this radiation within the equipment and equipment that can be advertently affected by RFI should have RF shielding built into its design.

- Hydrazine and its Methyl Derivatives (H008)

The Orbiter/cargo umbilicals should be designed to limit spillage of fluids at the pad or other loading areas to a minimum. Propellant systems designs should allow pressurization at the time of deployment from the Orbiter bay in space.

- APS Thruster Firing--Toxic Gas (H014)

Design of the APS systems should include electrical interlocks to produce inadvertent firing of the system, and provision should be made to bring the APS system up to operating pressure only just before deployment from the Orbiter in space. Covers or shields over APS thrusters should be provided to prevent the release of toxic vapors or liquids.

- Pyrotechnics--Safed (H015) and Armed (H017)

Ordnance firing circuits must be designed so that after one failure, a second failure will not fire the circuit. The payload design should include the location of the pyrotechnic initiators for easy accessibility when the cargo is in the Orbiter bay.

- Batteries (H019)

Battery and battery connector designs should include the use of plug-in type connectors to cut down the possibility of arcing. The batteries should also have adequate vents that are connected to the Orbiter vent system that would preclude possible battery case overpressurization.

- GF_2 (H025)

An F_2 sensor at the vent side of the heat exchanger is required to detect possible GF_2 or LF_2 leaks into the heat exchanger.

A heat exchanger in/around the F_2 tanks is required to help passivate the F_2 tank and lines prior to loading LF_2 and control the LF_2 temperature after loading.

- Cryogenic LN_2 (H026)

Insulation or shielding should be provided to prevent personnel contact with cryogenic temperatures.

- LF_2 (H028)

Design of the LF_2 system should allow maintenance of low tank pressure with the LN_2 cooling system until this unit is deployed from the Orbiter.

The F_2PU should contain a minimum of electronics and should be hermatically sealed with an F_2 compatible material.

- Radiological (RHU) (H029)

The RHU's should include sufficient shielding to prevent exposure of operational personnel to radiation.

- Krypton 85 (H030)

No new applicable payload design requirements.

- LF_2 Overpressure (H031)

Redundant pressure and temperature sensors should be provided. The system design should include a burst diaphram for venting after release from Orbiter in space and a remote operated vent valve for venting into disposal unit during ground operations. The vent system shall be designed so that no single failure allows leakage of fluorine. Double container concepts should be considered for LF_2 tank and line design to preclude leakage. F_2 sensors should be included between containers. If F_2 dumping in space (in case of abort) is prohibited, then an onboard cooling capability is required.

The LF_2 system design should allow maintenance of low tank pressure by LN_2 cooling until the unit is deployed from the Orbiter in space. Final F_2 tank pressurization should be performed in space.

- High Temperature (H032)

The RTG cooling jacket design should allow installation without personnel contact with the RTG's. Payload design should allow for access to RTG's for installing the cooling jackets.

- Radiological (RTG) (H033)

The RTG location in the payload should allow installation and removal after the cargo is in the Orbiter bay. The RTG design should include adequate high temperature, fire, blast, and radiation shielding.

- RF (H034)

Power/lockout devices and on/off switches should be included to ensure that no single failure can cause inadvertent operation.

- N_2O_4 (H038)

Final pressurization should be delayed until just before the cargo is deployed from the Orbiter in space.

4.0 TUG/SEPS/SEOS CARGO PROCESSING PLAN

4.1 CARGO DESCRIPTION

The Tug/SEPS/SEOS cargo consists of the cryogenic reusable Tug (MSFC base line configuration) and the SEOS. The SEPS is hard docked and locked onto the Tug with explosive release mechanisms. The SEOS is similarly attached to the SEPS. (Neither the SEPS nor SEOS is structurally attached to the Orbiter bay.) A sketch of the Tug/SEPS/SEOS Cargo is presented in Figure 15. A brief description of each element of the cargo follows.

4.1.1 Tug Description

The Tug is a high energy, reusable, propulsive stage that is carried in the Orbiter payload bay and is used to deliver/retrieve/service spacecraft. It is capable of delivering 6000 to 800 lb to geosynchronous orbit or retrieving 3000 to 4000 lb from geosynchronous orbit. Within this capability, it can deliver and retrieve payloads in low earth orbit or insert one spacecraft into an earth-escape trajectory.

The base line space Tug is composed of structures, propulsion avionics, and thermal control systems. Figure 16 presents the current general Tug configuration. General descriptions of these Tug systems follows:

4.1.1.1 Structures

The Tug is structurally attached to the Orbiter cargo bay at six points. Four attachment fittings are on the body shell; the other two are mounted on the deployment adapter and serve as pivoting points.

Umbilical systems between the Tug and Orbiter will be separated prior to Tug deployment and will provide reconnect capability for the Tug LO_2 and LH_2 vent and propellant lines, GHe inerting purge, and those electrical functions required to maintain the Tug during the reentry. All lines and cables between the Tug and Orbiter will be routed along the inside of the cargo bay from the aft service points defined by the Orbiter base line. The main propellant tank fill and drain lines and pressurant lines are attached to interface panels in the payload bay and are accessible for servicing through the Orbiter.

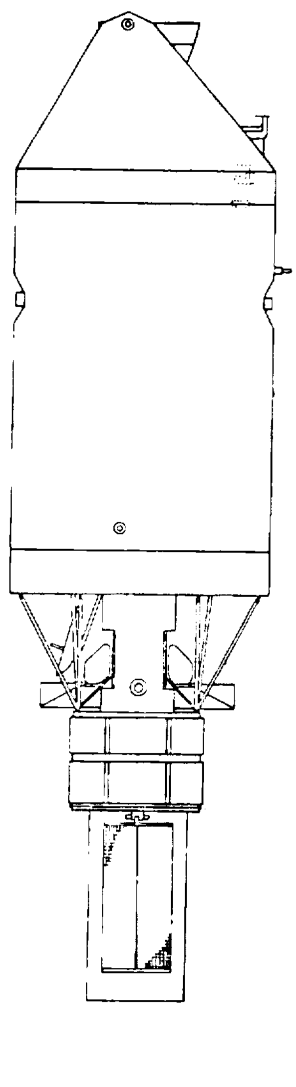


FIGURE 15. TUG/SEPS/SEOS CARGO CONFIGURATION

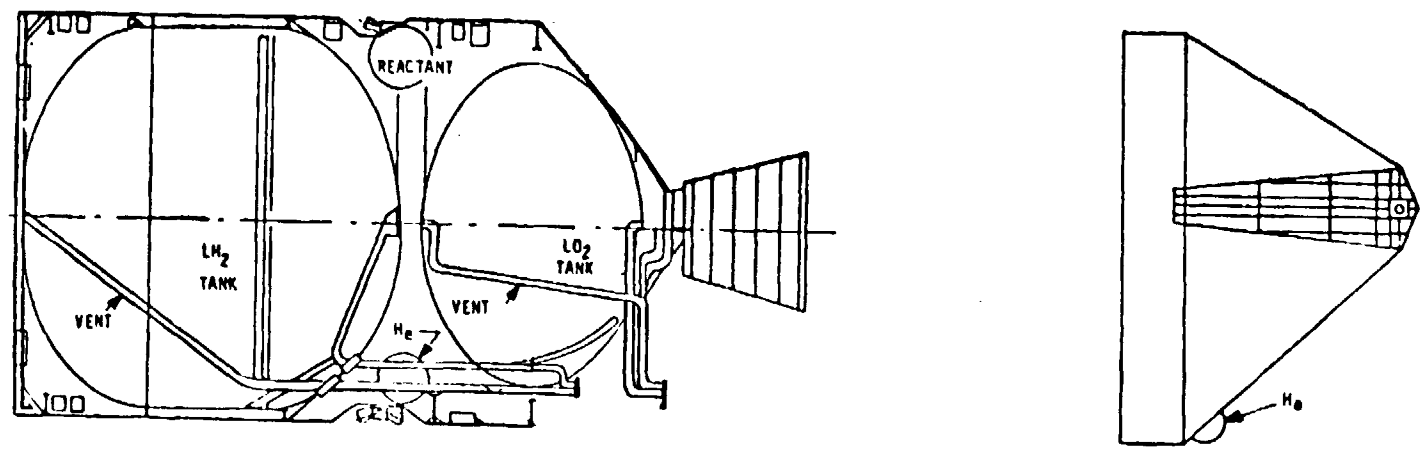


FIGURE 16. TUG CONFIGURATION

4.1.1.2 Propulsion

The propulsion system provides a vacuum thrust of 15,000 lb from a derivative of the flight-proven Pratt and Whitney RL10 engine. The main propellants, LH_2 and LO_2, are pressurized from a helium pressurization system. The helium pressurization system consists of two 4.5 ft^3 bottles pressurized to 3200 psig.

The Tug auxiliary propulsion system provides three axis attitude control and small ΔV translation maneuvers for the Tug. It is a regulated monopropellant hydrazine system with four pods of six thrusters each. Propellant is supplied from three hydrazine tanks pressurized by helium.

4.1.1.3 Avionics

The Avionics System consists of the communications; guidance; navigation and control; data management; measurement, power, and distribution subsystems. The system design provides a high degree of in-flight autonomy with ground commands generally required only for safety inhibits, mission contingencies, and navigation updates.

The Tug electrical power is a 28 Vdc system composed of power sources, power processing, and distribution and control equipments. In addition to providing subsystems power, it will provide up to 600 W of power to the spacecraft while it is attached to the Tug. While the Tug is in the Orbiter bay, power is supplied to the Tug power bus from the Orbiter.

The Tug power source consists of two Tug designed fuel cells each rated at 2.0 kW with 3.5 kW peak. Each fuel cell is capable of supplying the total load. The fuel cell system has dedicated reactant tanks. An auxiliary battery rated at 25 A-hr supplements in rush current requirements for motor loads and powers up the fuel cells.

4.1.1.4 Thermal Conditioning

Thermal conditioning of the Tug is accomplished by both active and passive means. The fuel cells waste heat is rejected to space by an active thermal control system using Freon 21 circulated by dual redundant pumps through radiators, selector valves, a temperature control valve, and the fuel cell heat exchanger. The forward skirt panel mounted avionics will be cooled by lightweight radiation shields and heated by electrical heaters controlled by the central computer. Heat pipes provide thermal control when the Tug is perpendicular to the sun. The temperature of the avionics in the intertank area will be controlled by heat pipes alone.

4.1.1.5 Summary of Hazardous Materials/Systems

These Tug systems will require checkout and servicing during ground processing. The following hazardous materials are carried by the Tug and are of concern in processing the Tug:

- LO_2
- LH_2
- Hydrazine
- High Pressure Helium
- High Pressure Nitrogen
- Pyrotechnics
- Electrical
- Pyrotechnics
- Batteries
- Hydraulics

4.1.2 SEPS Description

The SEPS is a versatile and efficient unmanned space vehicle that can complement the Shuttle and the Orbit-to-Orbit Shuttle/Tug for both earth-orbital and planetary missions. It can retrieve, as well as deliver, large payloads from geosynchronous orbit, or perform space servicing of several geosynchronous satellites during a single mission. The SEPS can also transport payloads to planets, comets, and asteriods that are difficult or unreasonable with chemical vehicles alone. The earth orbital version was selected for this study.

This multipurpose space vehicle that only weighs about 6,000 lb, can generate a total impulse equivalent to a 24,000-lb chemical stage. This is achieved with the 3000 sec specific impulse of a low thrust ion propulsion system.

Figure 17 presents the basic earth orbital SEPS configuration. The primary subsystems on SEPS are described below.

4.1.2.1 Propulsion

The basic power source of SEPS is the dual solar array (131- by 1230-in. each), which provides 21 kW of power. It is assumed that the solar arrays will not be extended during ground processing at KSC. This is primarily due to the space and complex fixturing requirements for 1 g operation.

The thrust is provided by an ion thruster array assembly consisting of nine gimballed thrusters (seven normal and two spare). The thruster array has a translation mechanism that will position any thruster 2 in. past the SEPS center line.

The propellant, mercury (3200 lb), is fed by Freon 113 pressurant. At worst case it is assumed that this propellant and pressurant must be loaded during ground processing at KSC.

4.1.2.2 Reaction Control

This system, required for orientation during coast and docking, consists of 18 thrusters and 2 hydrazine storage tanks with appropriate valving. The propellant is pressurized by GN_2.

4.1.2.3 Energy Storage and Distribution

The system provides the flight batteries, converters, inverters, battery chargers, regulators, etc., required for the payload and onboard systems.

4.1.2.4 Miscellaneous Systems

Other systems onboard requiring checkout (no significant servicing functions) during ground processing include the data handling, command computer, guidance and control, docking, and communications

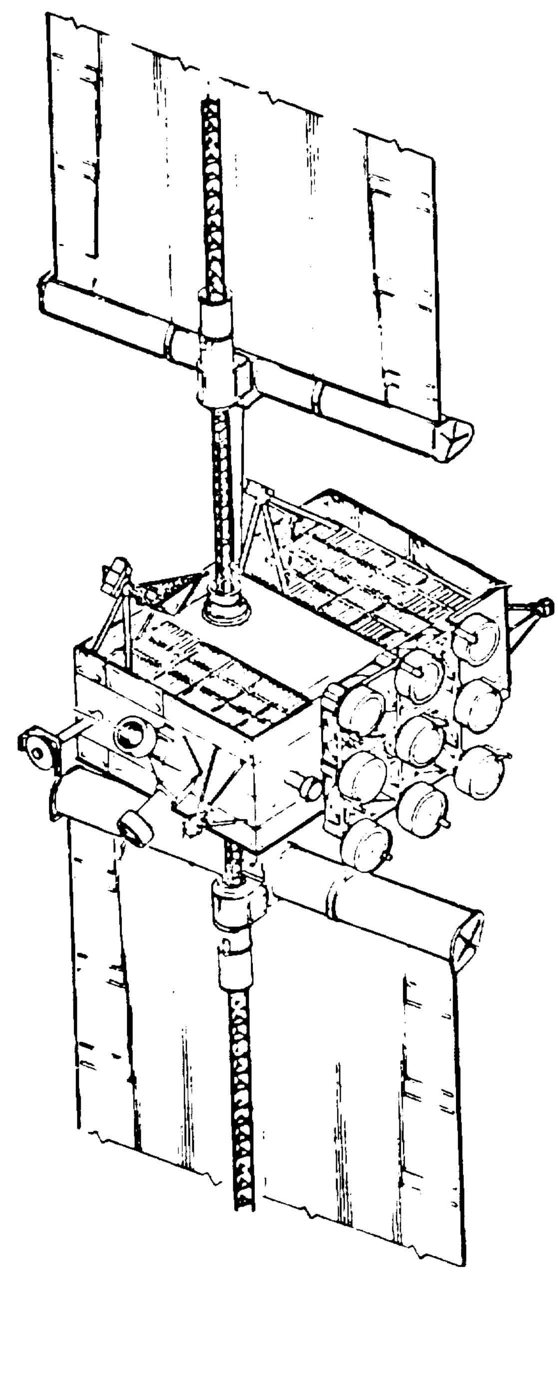


FIGURE 17. SEPS CONFIGURATION

systems. However, the docking system includes a laser device that induces a unique hazard during checkout.

4.1.2.5 Summary of Hazardous Materials/Systems

The hazardous materials/systems for ground processing are:

- Mercury ($\sim$ 3000 lbs)
- High Pressure Freon 113
- Hydrazine
- High Pressure GN_2
- Pyrotechnic
- Laser Radar
- High Temperature (Heater)
- Electrical
- Batteries.

4.1.3 SEOS Description

The mission of SEOS is to investigate sensing techniques for measuring environmental phenomena from a geosynchronous orbit. Typical phenomena to be studied are tornadoes, hurricanes, hail storms, air pollution, floods, water pollution/biological productivity, navigational hazards, soil moisture, water availability, forest fires, shoreline erosion, and crop infestation.

The major piece of equipment onboard is a Cassegrainian telescope, including a light baffle and focusing mechanism. The sensor assembly includes the following:

Quantity	Description
1	Linear Silicon Diode Array
12	Photomultipliers
9	Silicon Detectors
6	Mercury Cadmium Telluride Detectors
1	Immersed Thermistor Bolometer

Also, there is a data collection system and antenna for data management. Figure 18 presents a preliminary sketch of the SEOS concept.

Supporting subsystems include:

- Structure-- cruciform structure.
- Environmental Control-- passive cooling with heat pipes.
- Guidance and Navigation --sun and earth sensors, star trackers, and momentum wheels.
- Propulsion--hydrazine thruster system for orbit trim, station keeping, and momentum wheel unloading.
- Telemetry, Tracking, Command--transponder for range and rage rate, s-band telemetry.
- Electrical--two rotating solar arrays. Direct energy transfer-type power conditioning.

4.1.3.1 Summary of Hazardous Materials

The only hazardous materials of concern in processing SEOS are hydrazine, high pressure GN_2, electrical, RF, and pyrotechnics.

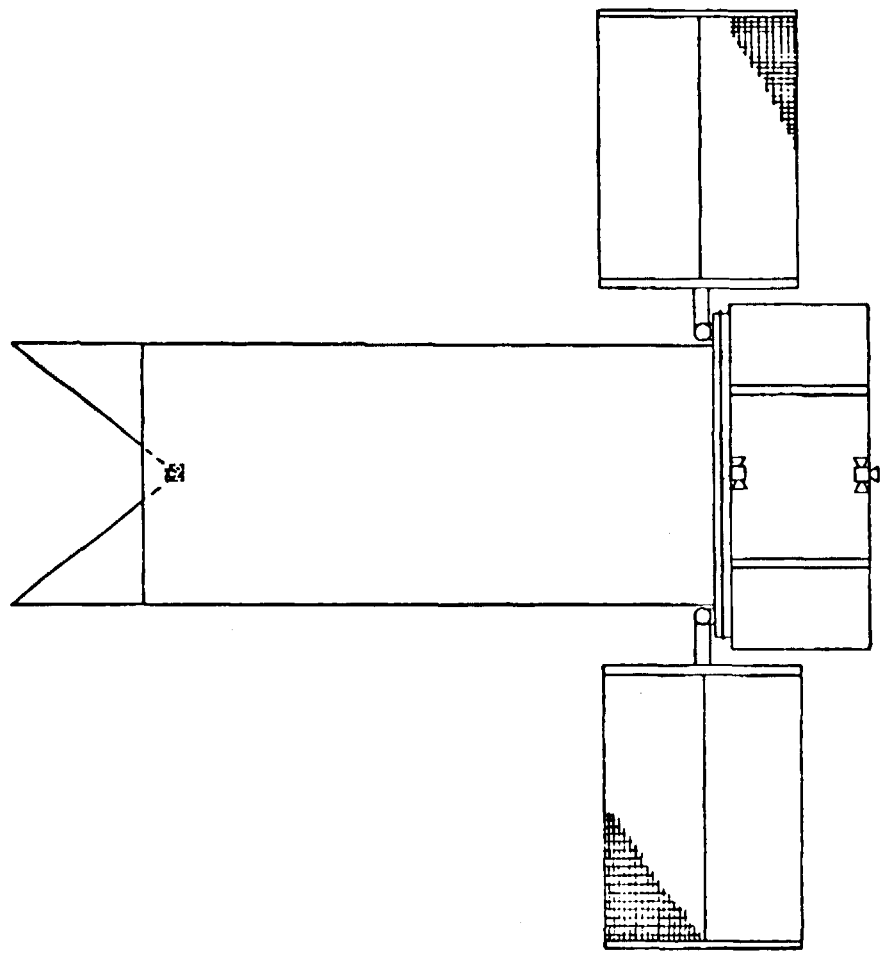


FIGURE 18. SEOS CONFIGURATION

4.2 PROCESSING SCENARIO

The Tug/SEPS/SEOS processing scenario shows a likely sequence of operations essential to process this cargo for the prelaunch, launch, and post-flight phases of its operational cycle. Buildings and areas have been identified that most reasonably accommodate the major operations required to process the individual elements (Tug, SEPS, and SEOS) of this cargo as well as those for the combined cargo.

Throughout the analysis there has been a continuous endeavor to evolve the best practical sequence of activities for a reasonably safe and timely set of prelaunch and post-launch processing plans. This has been reflected in our selection of the relative placement of activities with respect to one another and the location where performed.

The scenario (Figure 19) covers the full cycle of operations as follows:

- Tug is off-loaded at KSC airstrip and transported to SAEF #1 where it is inspected, shipped loose parts assembled, and the auxiliary propulsion system loaded and safed.

- The SEPS and SEOS are moved from the air strip to the AE Hanger where each is inspected, shipped loose parts assembled, and functionally tested. They are then transported to the Propellant Lab 60A where in the case of SEPS, both the auxiliary propulsion system and the low thrust propulsion system are loaded with hydrazine and mercury, respectively. The SEOS propulsion system is, also, loaded at 60A.

- SEPS and SEOS are transferred to SAEF #1 where they are mated with the Tug to form the designated cargo.

- While at SAEF #1, the cargo undergoes integrated systems tests and the installation of Class A ordnance. Since the cargo is to be loaded at the pad through the PCR, it is installed in a canister and transported to the launch pad.

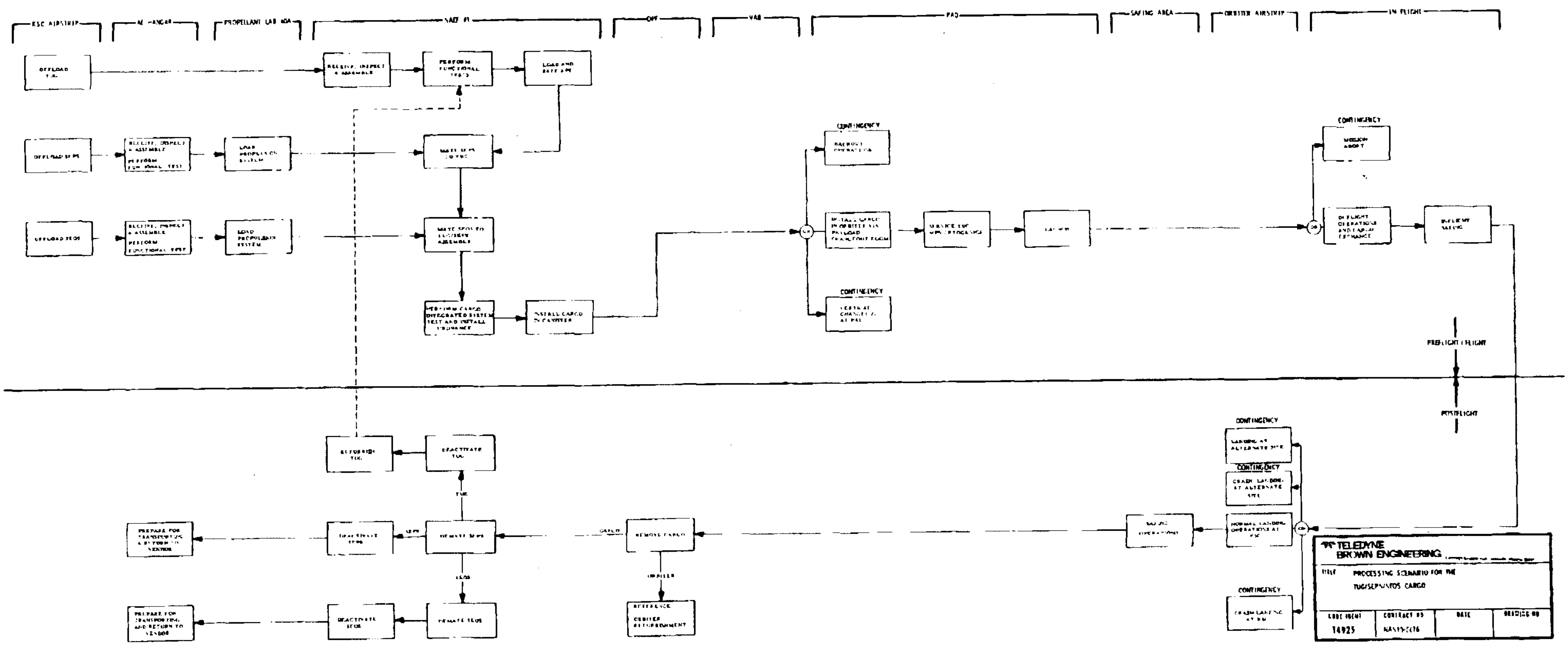


FIGURE 19. PROCESSING SCENARIO FOR THE TUG/SEPS/SEOS CARGO

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- At the pad, the PCR is extended and the cargo loaded canister is lifted from a transporter into the PCR. The batteries are installed, the main power bus is verified, and the cargo is installed in the Orbiter bay. The Orbiter/cargo interfaces are made and verified, the Orbiter bay is closed, and the PCR is retracted.

- During the countdown, the Shuttle propellants are loaded and the Tug Main Propulsion System is loaded with cryogenics.

- In-flight operations are performed and cargoes are exchanged. It was assumed, for this analysis, that the returning cargo would also be a Tug/SEPS/SEOS to establish a full operational cycle for such a cargo. Prior to the actual retrieval of the cargo, some safing operations are performed, and after the cargo has been retrieved into the Orbiter bay more safing activities take place. These constitute in-flight safing as shown on the scenario.

- Assuming a normal Orbiter landing, Orbiter safing takes place prior to towing the Orbiter to the OPF. At the OPF, the cargo is removed from the Orbiter and transported to SAEF #1 where SEOS and SEPS are demated from the Tug. All three elements (Tug, SEPS, and SEOS) are deactivated.

- SEPS and SEOS are prepared for transporting and are returned to their respective vendors for refurbishment. The Tug is refurbished at SAEF #1 and either sent to storage, or put back into operation.

In addition to the normal processing base line previously discussed, five contingency situations are presented. Two contingency situations at the pad are shown:

- Backout Operations

- Vertical Changeout

The third contingency, Mission Abort, is shown as an alternative to the normal in-flight operations. The fourth and fifth contingencies are:

- Landing at Alternate Site

- Crash Landing

These are presented as alternatives to the normal landing operations at KSC and contingency flow plans for these situations are included in Volume 4.

4.3 PROCESSING FLOWS

This section presents the Tug/SEPS/SEOS Launch Site Processing Flow Plans that were derived during this study. These flow plans identify each major operation necessary to prepare the payload for flight and post-flight refurbishment and acknowledge the payload hazardous parameters that exist during these operations.

A top-level flow was developed to show individual payload operations, cargo operations, launch operations, and post-launch operations. This top-level flow is essentially an index of operations at different areas and was expanded into a detailed operational sequence for each cargo. This detailed operational sequence was an iterative process and through a series of iterative tradeoffs the normal base line processing flow plans were formed.

4.3.1 Top-Level

While the scenario for the Tug/SEPS/SEOS cargo shows basic and essential operations to enable its processing, a slightly different format was established to be used as a top level functional flow. The top-level Tug/SEPS/SEOS Launch Site Processing Flow Plan is presented in Figure 20. This figure shows nine major areas that provide convenient breakouts for the second level functional flows and have been addressed at the first level. A brief description of each block in this processing sequence is provided. Contingency and reference blocks are included on this chart to show the chronological relationship of the activities (these blocks will not be discussed in this section).

- 1.0 Tug Premate Processing

- 2.0 SEPS Premate Processing

- 3.0 SEOS Premate Processing

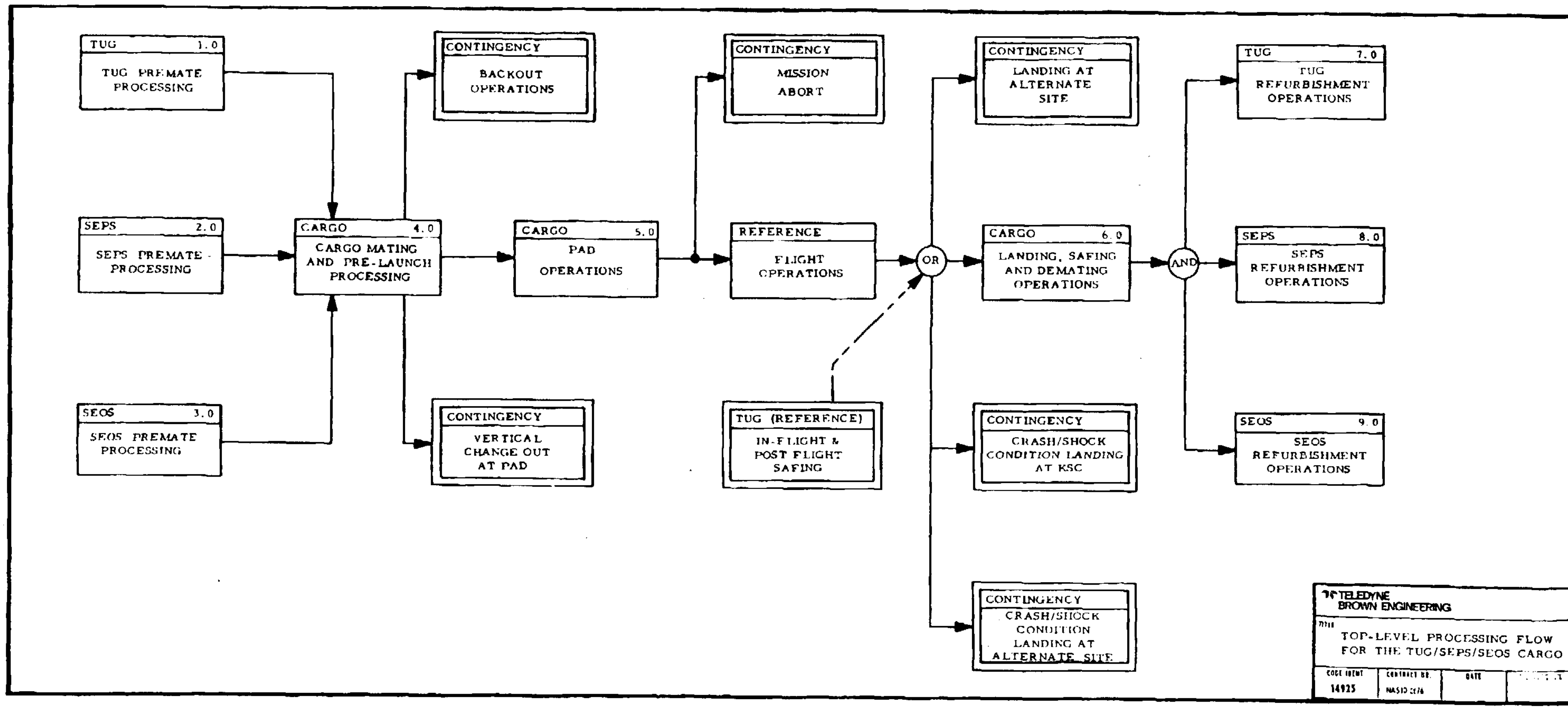

FIGURE 20. TOP LEVEL PROCESSING FLOW FOR THE TUG/SEPS/SEOS CARGO

- 4.0 Cargo Mating and Prelaunch Processing
- 5.0 Pad Operations
- 6.0 Landing, Safing, and Demating Operations
- 7.0 Tug Refurbishment Operations
- 8.0 SEPS Refurbishment Operations
- 9.0 SEOS Refurbishment Operations

4.3.2 Normal Base Line

The Tug/SEPS/SEOS second level functional flow diagram referred to as the normal base line processing flow is an expansion of the first level with sufficient details to enable a hazards analysis to be performed from the second level functional event sheets.

The Normal Base Line Processing Flow (Figure 21) represents the output of an iterative process. Many feasible options in sequencing certain activities were examined and cursory analyses were made to weigh their respective advantages and disadvantages considering the parameters of safety, time, and facilities. Through this process some hazardous operations were either eliminated, reduced, or replaced by less hazardous ones, or the sequence and/or locations changed so as to have a lesser impact. This process led to the evolvement of the normal base line processing flow. For each individual item on these flows, a functional event sheet was prepared to define the operation to a level necessary to identify all hazards, estimate operations times, and identify GSE.

Certain basic assumptions were made during the formulation of the normal base line processing flows. These are discussed below.

- Mission--It is assumed, for study continuity, that an expended Tug/SEPS/SEOS is returned.
- Insulation Purge--Because of the preliminary nature of the data available, the high performance insulation (HPI) purge requirements are uncertain. To cover all cases, continuous purge is used during preflight processing for the SEPS and SEOS and no purge is used during ground processing of Tug. It is assumed that the Tug HPI is

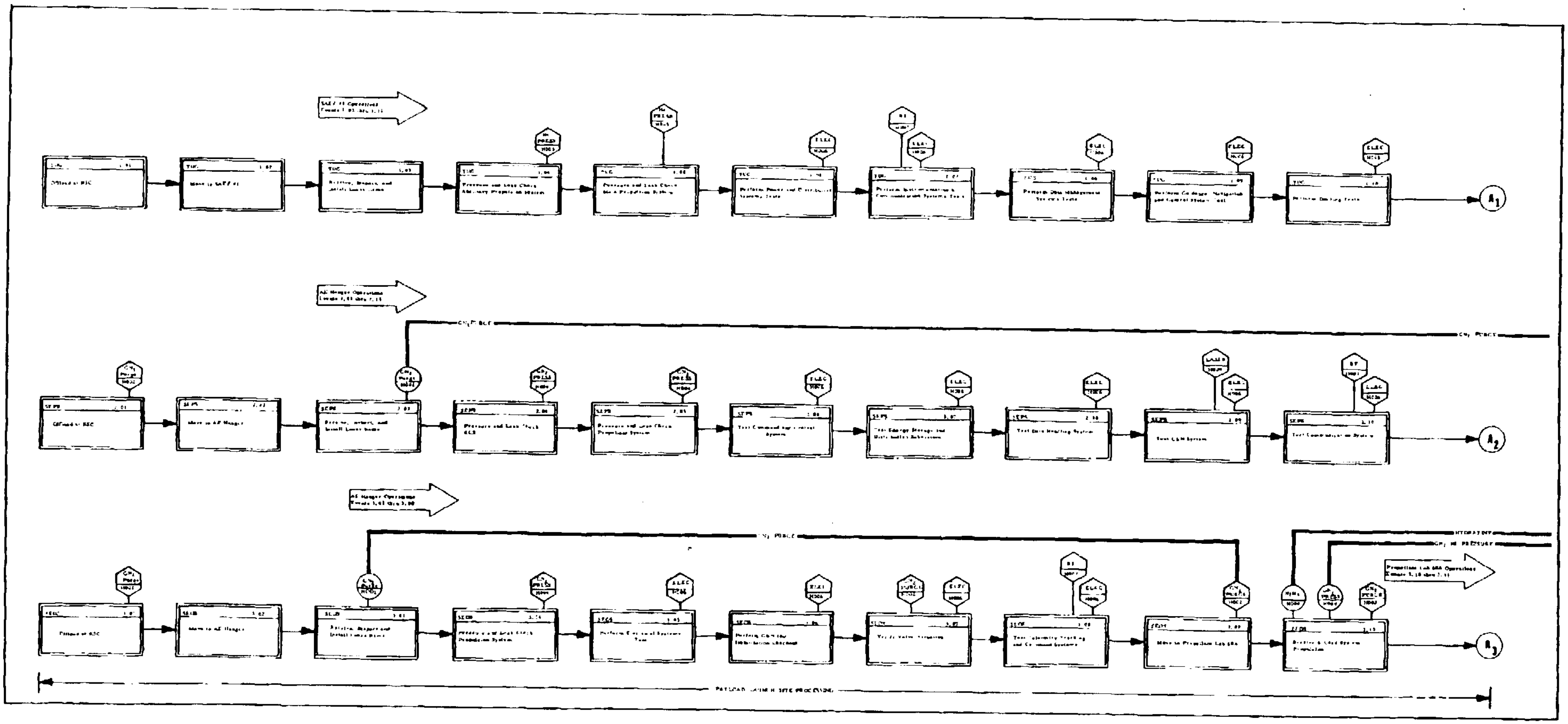

FIGURE 21. NORMAL BASE LINE PROCESSING FLOW FOR THE TUG/SEPS/SEOS CARGO (Sheet 1 of 9)

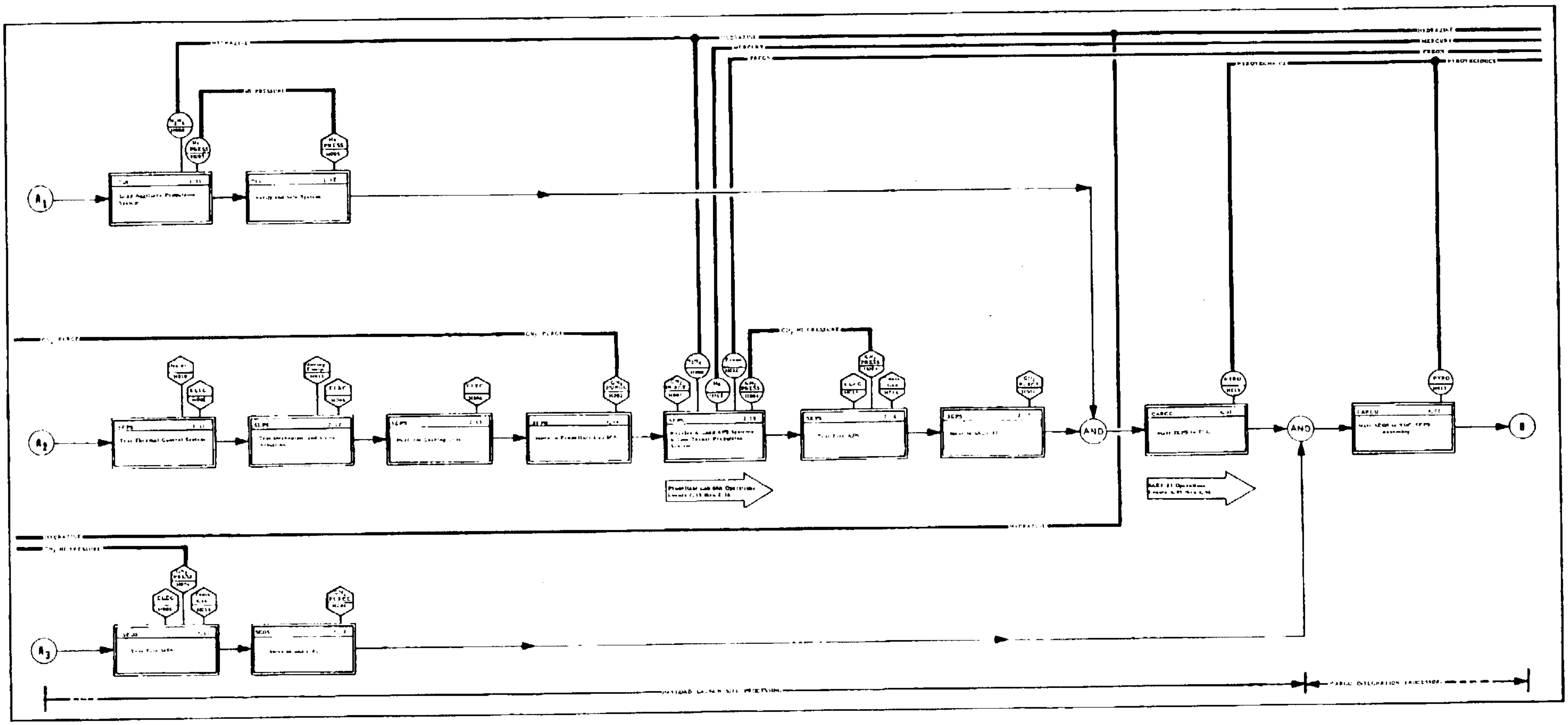

FIGURE 21. NORMAL BASE LINE PROCESSING FLOW FOR THE TUG/SEPS/SEOS CARGO (Sheet 2 of 9)

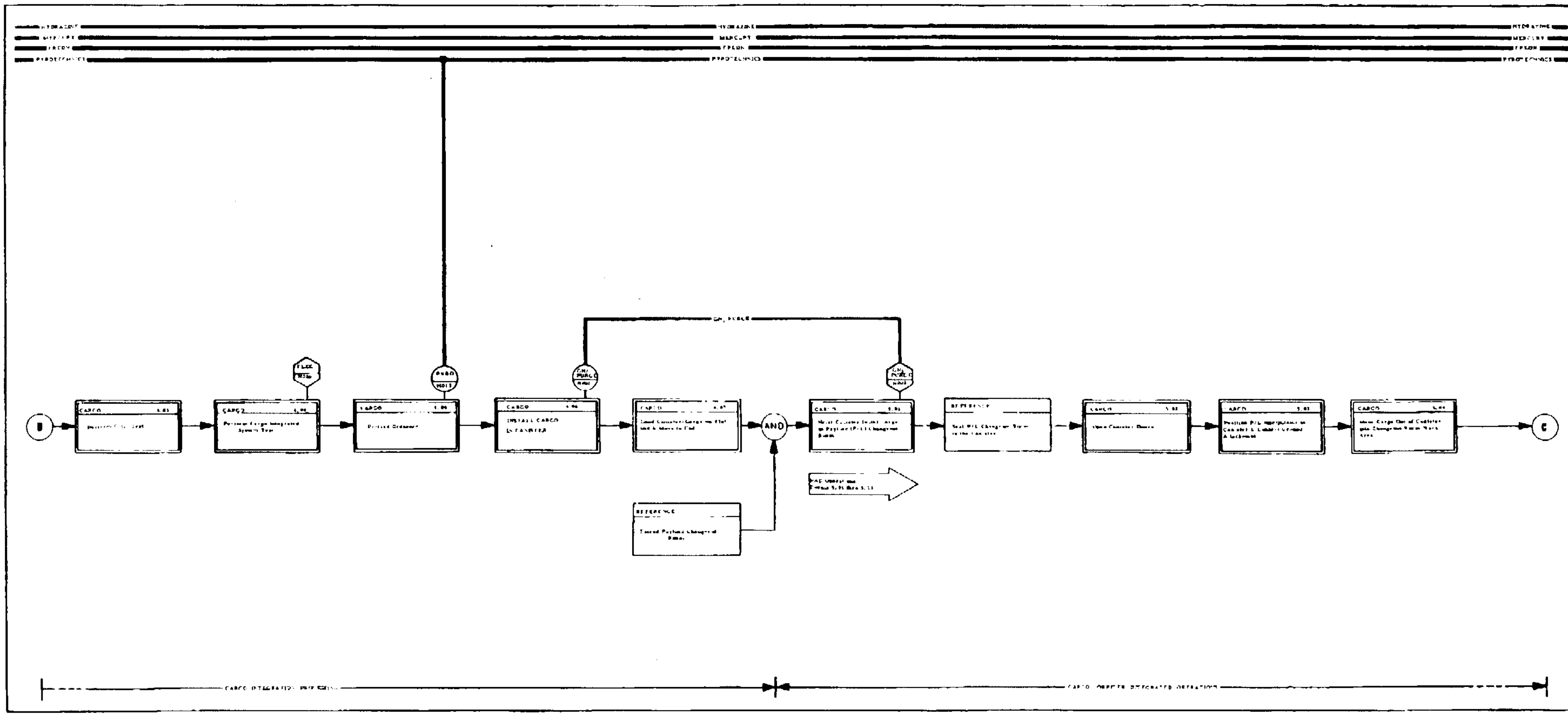

FIGURE 21. NORMAL BASE LINE PROCESSING FLOW FOR THE TUG/SEPS/SEOS CARGO (Sheet 3 of 9)

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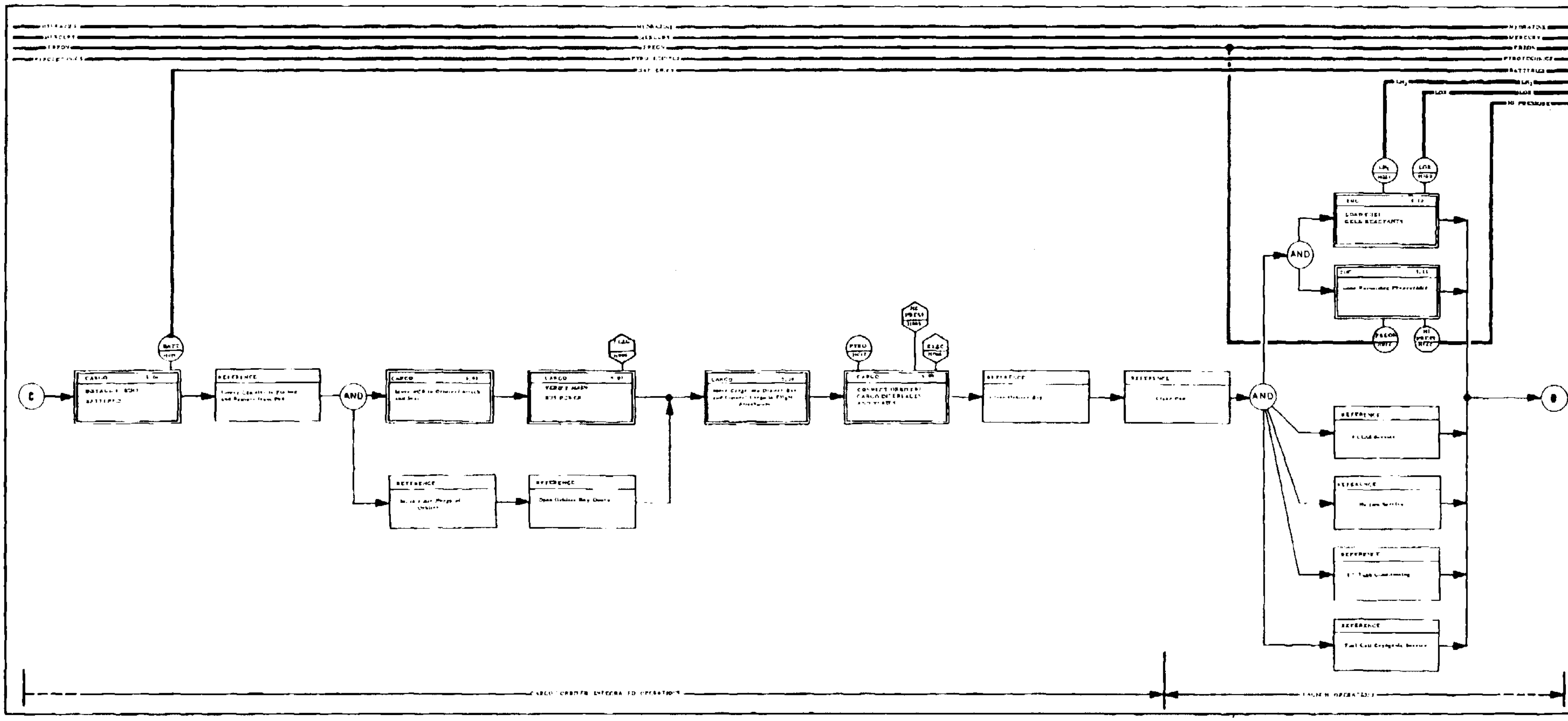

FIGURE 21. NORMAL BASE LINE PROCESSING FLOW FOR THE TUG/SEPS/SEOS CARGO (Sheet 4 of 9)

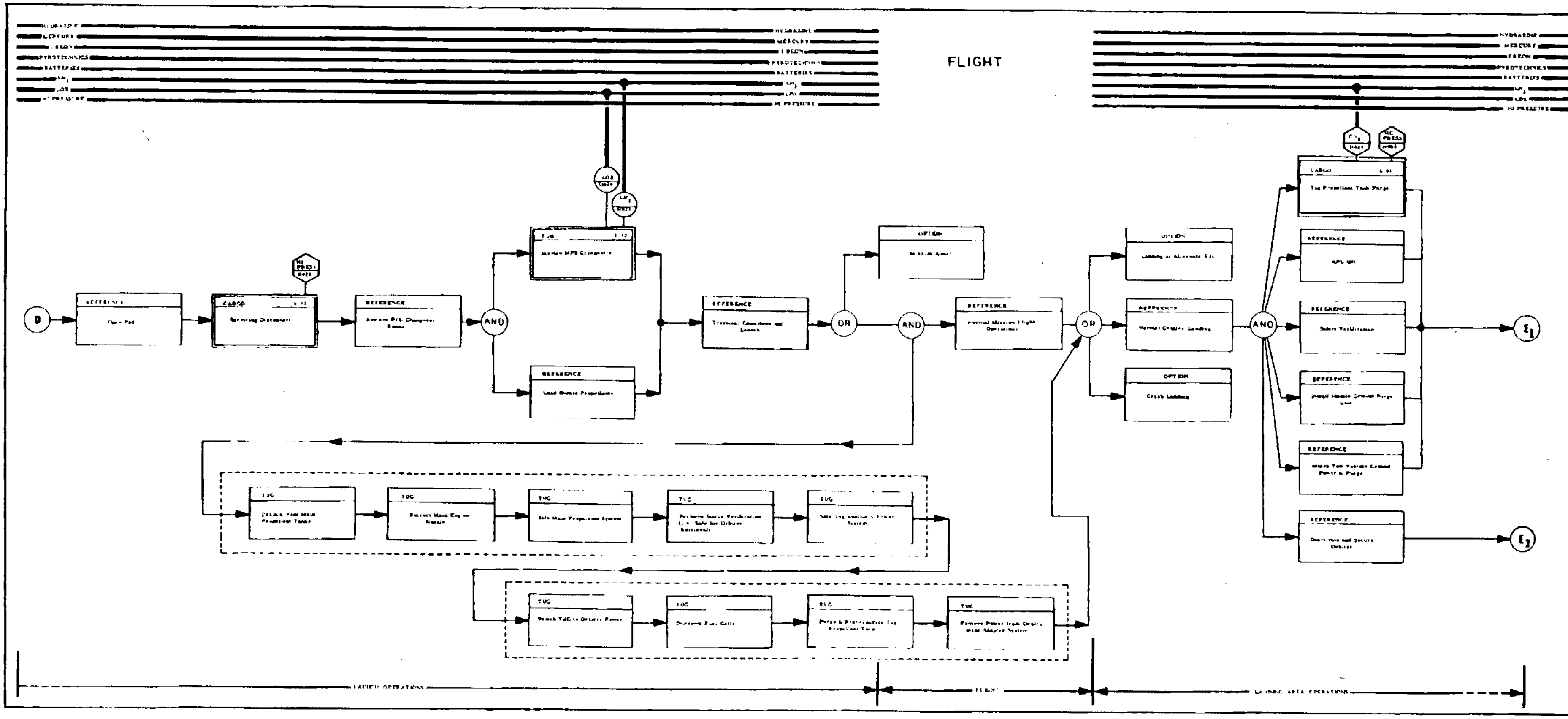

FIGURE 21. NORMAL BASE LINE PROCESSING FLOW FOR THE TUG/SEPS/SEOS CARGO (Sheet 5 of 9)

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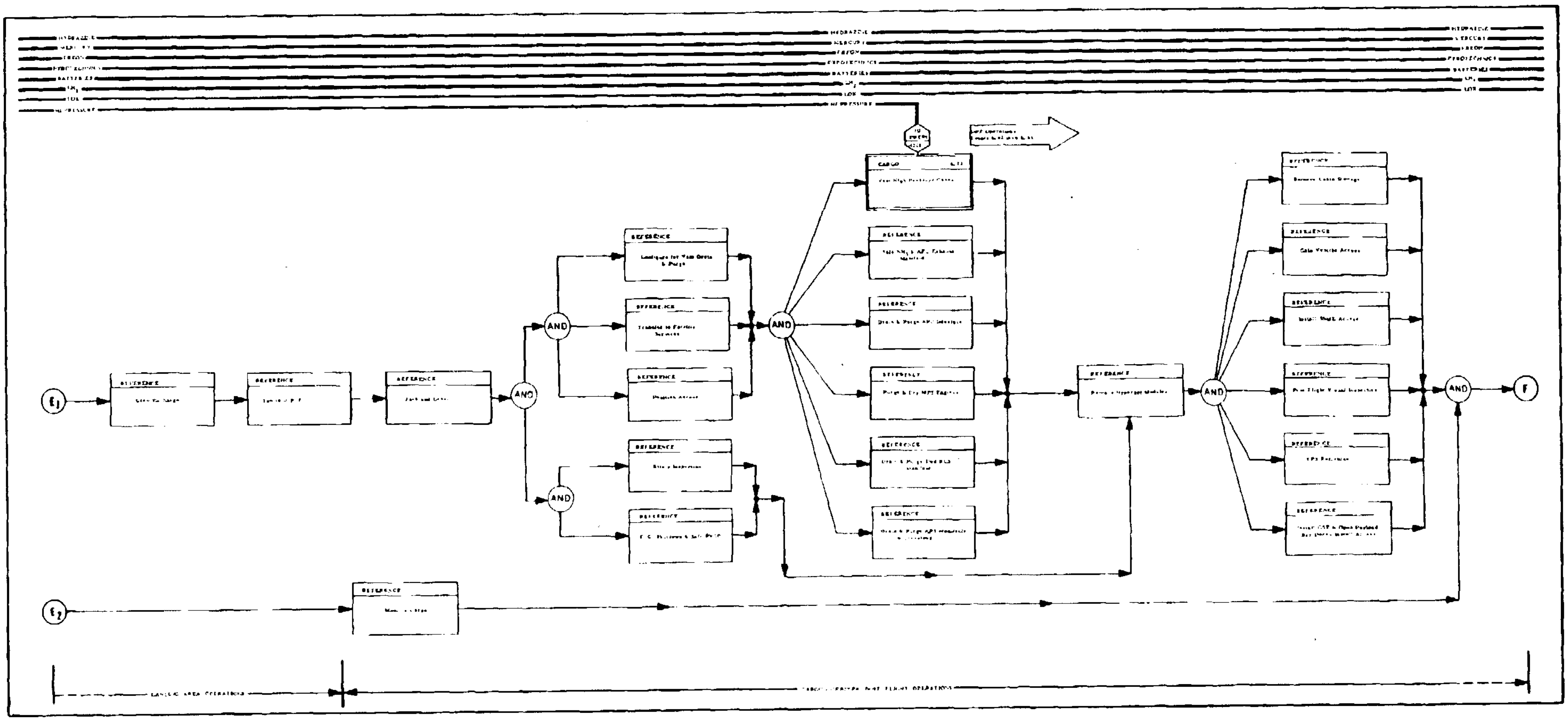

FIGURE 21. NORMAL BASE LINE PROCESSING FLOW FOR THE TUG/SEPS/SEOS CARGO (Sheet 6 of 9)

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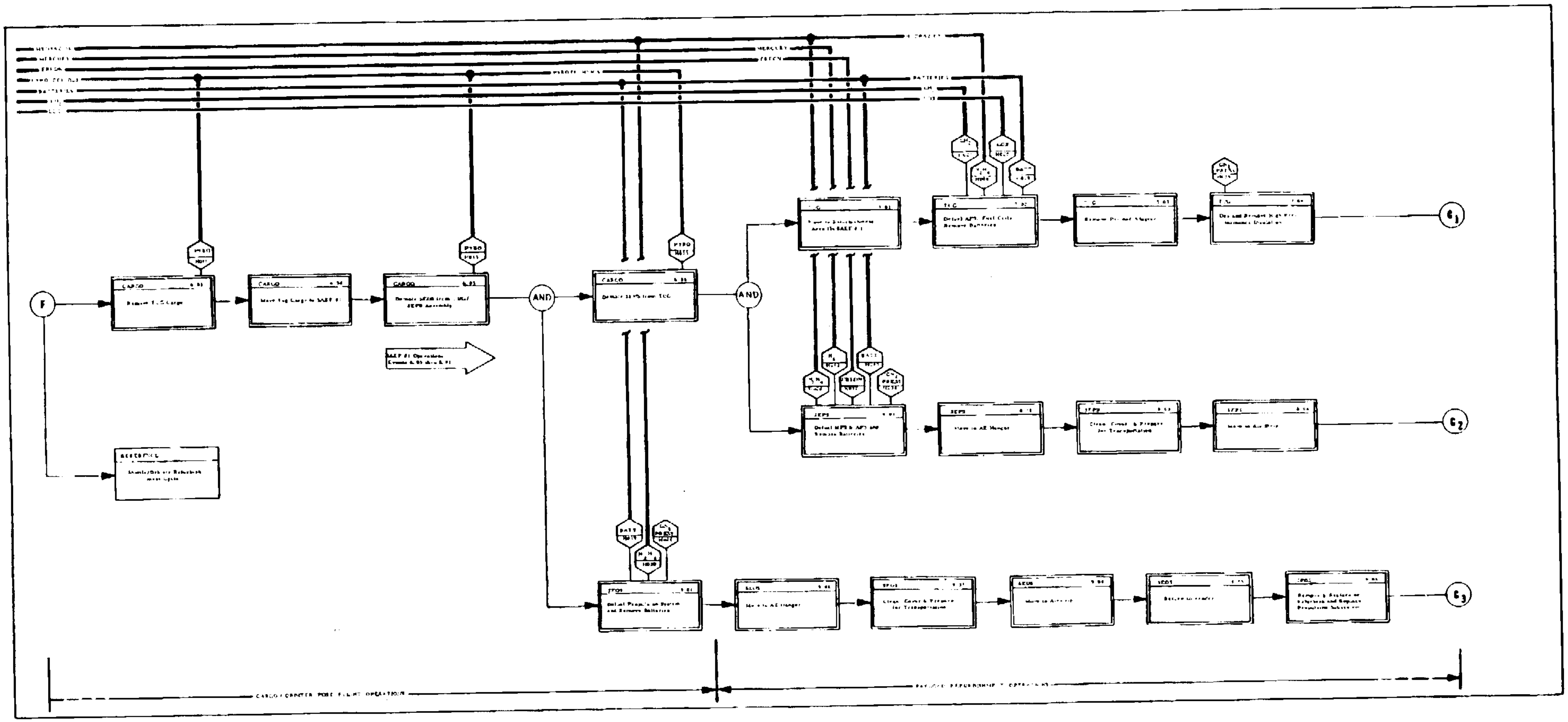

FIGURE 21. NORMAL BASE LINE PROCESSING FLOW FOR THE TUG/SEPS/SEOS CARGO (Sheet 7 of 9)

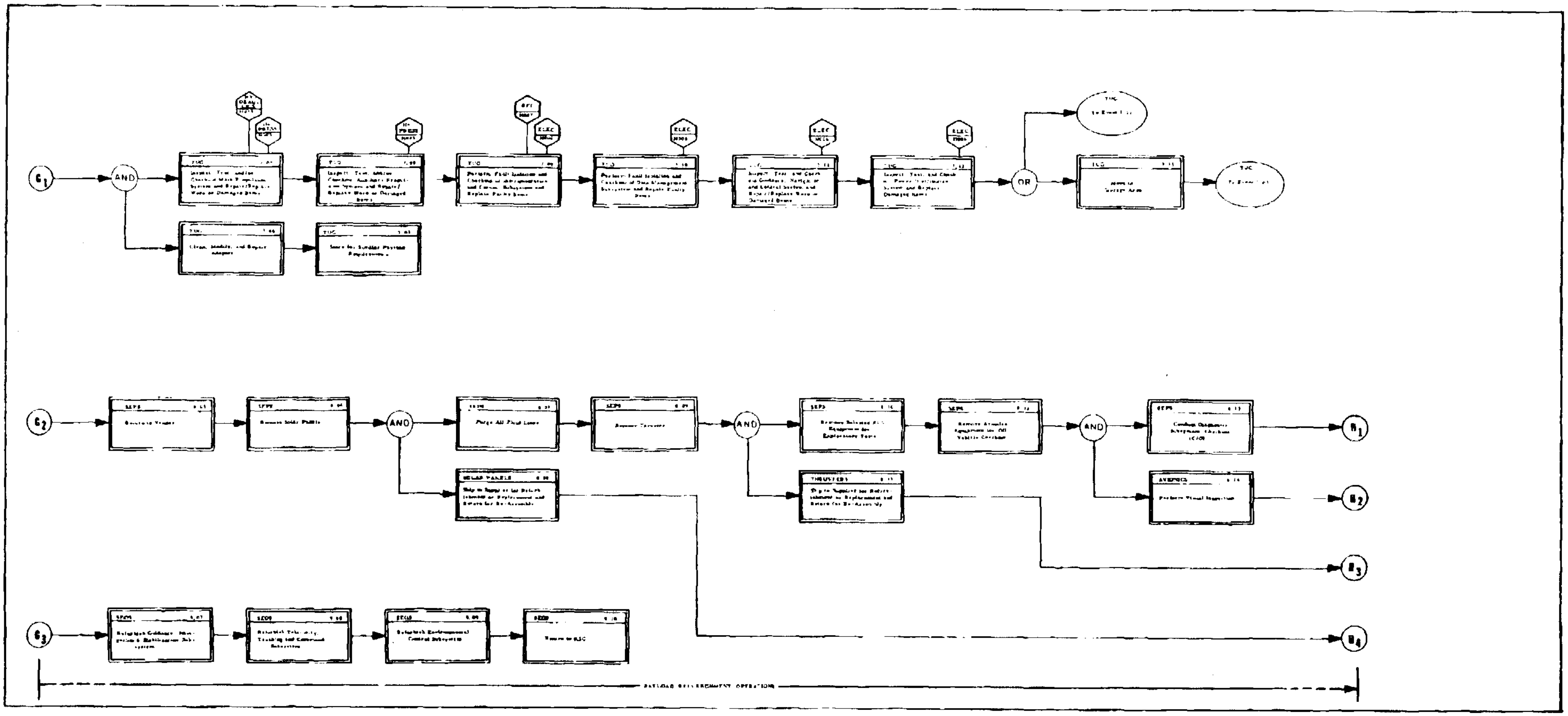

FIGURE 21. NORMAL BASE LINE PROCESSING FLOW FOR THE TUG/SEPS/SEOS CARGO (Sheet 8 of 9)

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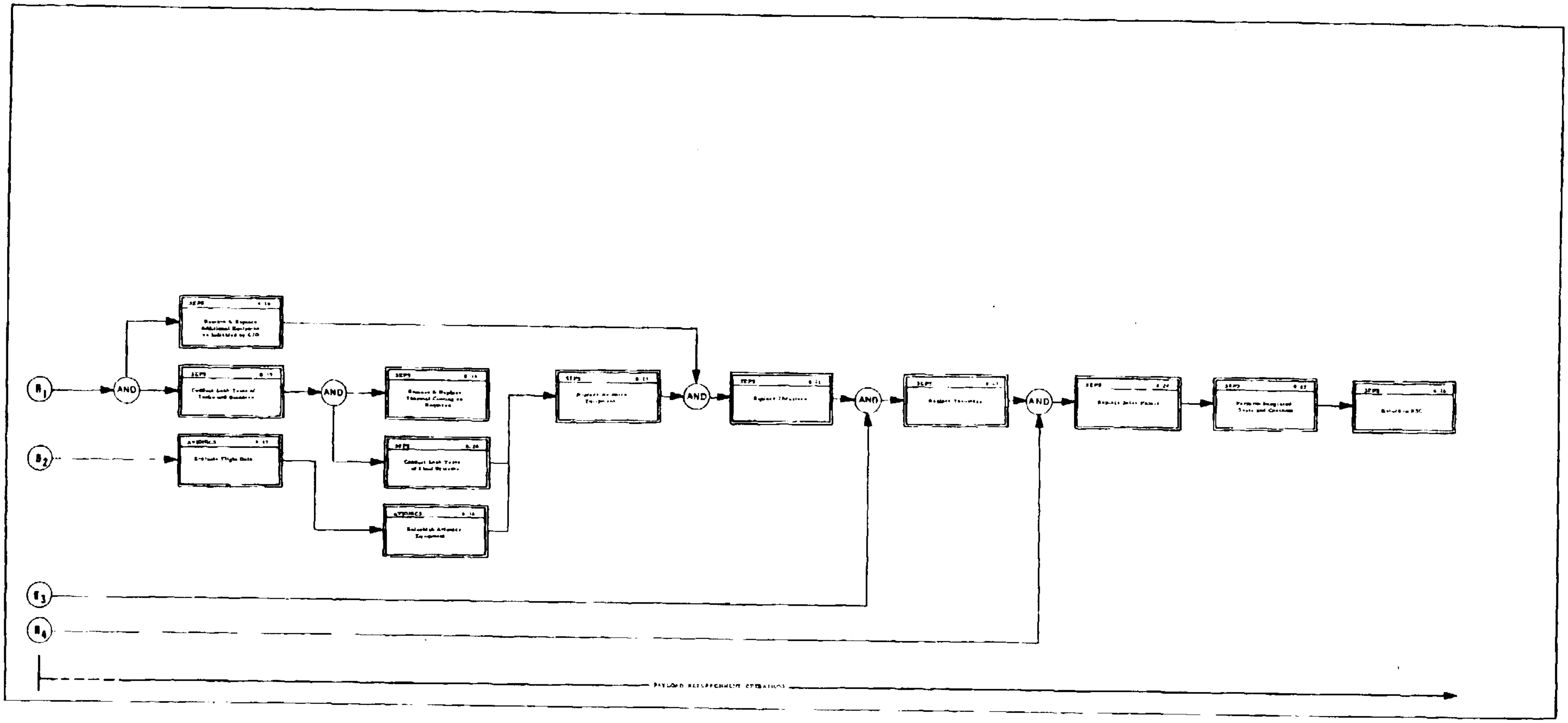

FIGURE 21. NORMAL BASE LINE PROCESSING FLOW FOR THE TUG/SEPS/SEOS CARGO (Sheet 9 of 9)

95 - A

dried with hot GN_2, purged with He, and sealed during refurbishment. This seal is assumed to be good throughout preflight processing. It is further assumed that the HPI on SEPS and SEOS will be replaced during refurbishment.

- Refurbishment--It is assumed that the major Tug refurbishment activity is performed at KSC and that, because of the highly specialized equipment requirements, the SEPS and SEOS are returned to the vendor for refurbishment.

- Other--To explore the processing of the mercury hazard on SEPS, it is assumed that the mercury and its pressurant, Freon 113, are loaded during processing (and not preloaded at the vendor).

4.3.3 Options to Normal Base Line and Trade Studies

In the development of the Normal Base Line Processing Flows, alternate flow plans were studied and analyzed to develop the optimum operational sequence of flow for processing the Tug/SEPS/SEOS cargo. These options present areas of the normal base line processing flow concept that required additional study and trade offs to ensure the selection and development of the most feasible and time/cost effective approach as far as the safety aspects are concerned.

Four major options to the Tug/SEPS/SEOS selected normal base line concept were investigated:

- Load cargo into Orbiter at the OPF
  - -- Not fueled
  - -- SEPS fueled.

- Load Tug only into Orbiter at OPF then mate SEPS and SEOS with Orbiter at the pad.

- Load unfueled cargo into Orbiter at the pad.

- Load cargo into the Orbiter at the pad with the SEPS fueled and the APS systems fueled but not pressurized.

Each of the options has advantages and disadvantages. Many parameters were considered in making our base line selection, such as types of propellants, processing time, checkout considerations, and effect of hazard. The fourth option was selected as the most advantageous for the normal base line from a practical safety standpoint.

The primary driver for selecting the fourth option was the problems associated with mercury, which is the SEPS's primary propulsion systems fuel. Because of the dispersive nature of mercury, a mercury leak could result in a mission scrub because of payloads and Orbiter contamination, which would require major refurbishment. The high surface tension and low viscosity properties of mercury cause it to break into small droplets upon impact. These droplets, some smaller than the eye can see, can cause electrical shorts and corrosion. Mercury cannot be readily absorbed or disolved and there are no practical solvents that can be used. In case of mercury leakage, disassembly will usually be required for cleanup.

Considering the constraints imposed by a mercury fueled SEPS, the cargo should be installed as late in the processing as possible. This would eliminate the option of loading the cargo into Orbiter at the OPF with the SEPS fueled. Considering the mercury loading process as resulting in the highest likelihood of spills, loading the SEPS with mercury after installation in the Orbiter bay would be very hazardous. This consideration would eliminate the options of loading the unfueled cargo into Orbiter at the pad and at the OPF. The difficulty from an access standpoint of integrating a payload in the cargo bay and the extended on line time required to integrate the SEPS and SEOS to the Tug along with the testing time required, eliminated the option of loading the Tug only into Orbiter at OPF and then mating SEPS and SEOS with Orbiter at the pad. The option of loading cargo into the Orbiter at the pad with the SEPS fueled and the APS systems fueled but not pressurized was most desirable because the SEPS loading was performed before mating and integration thereby minimizing other hardware exposure to mercury contamination, by a spill during loading. Integration of the payloads prior to mating with the Orbiter allows adequate time for cargo testing without affecting the Orbiter on line time.

4.4 FUNCTIONAL EVENTS DESCRIPTION

The purpose of these functional event sheets is to describe each Tug/SEPS/SEOS processing operation, give the sequence of events required to complete the operation, and estimate the time required. For each event in the operation, potential hazardous conditions are noted and cross-referenced to a hazards analysis. GSE and facilities associated with this operation are also shown. Hazardous materials or systems loaded or activated in a previous operation are indicated by hazard category.

The operation sequence portion of these functional event sheets define each of the Tug/SEPS/SEOS normal base line processing flow operations to a level necessary to identify all hazards, estimate operations times, and identify GSE. Eighty-eight normal base line processing flow operations were identified for the Tug/SEPS/SEOS cargo. Potentially hazardous conditions were identified as being associated with 64 of these 88 operations.

The functional event sheets for the Tug/SEPS/SEOS normal base line processing flow operations are in Appendix C.

4.5 WATERFALL/TIME LINE

The Tug /SEPS/SEOS Waterfall/Time line provides a visual guide to the series and parallel relationship of the various processing flow operations and is time-phased to show the time allocation for each operation. The processing flow operations were base lined early in this study in accordance with KSC Shuttle/Tug Turnaround Allocation, August 28, 1974. These time lines were not updated by subsequent changes or modifications to the operational allocations since these changes were not detrimental to the results of this study. The numbers and titles appearing on the events refer to the Tug/SEPS/SEOS functional flow diagram item numbers.

4.5.1 Normal Base Line

The normal base line processing flow time line is illustrated in Figure 22. This time line shows the complete flow of each element of this cargo from arrival at KSC to launch, for preflight operations, and from Orbiter landing to completion of refurbishment for post-flight operations. The Tug, SEPS, and SEOS are individually followed (through SAEF #1, AE Building, and Propellant Lab 60A) until they are mated into an integrated cargo at approximately 60 hr prior to launch. The pad time for this cargo is 30 hr. The Shuttle events for this time line are referenced but are not identified.

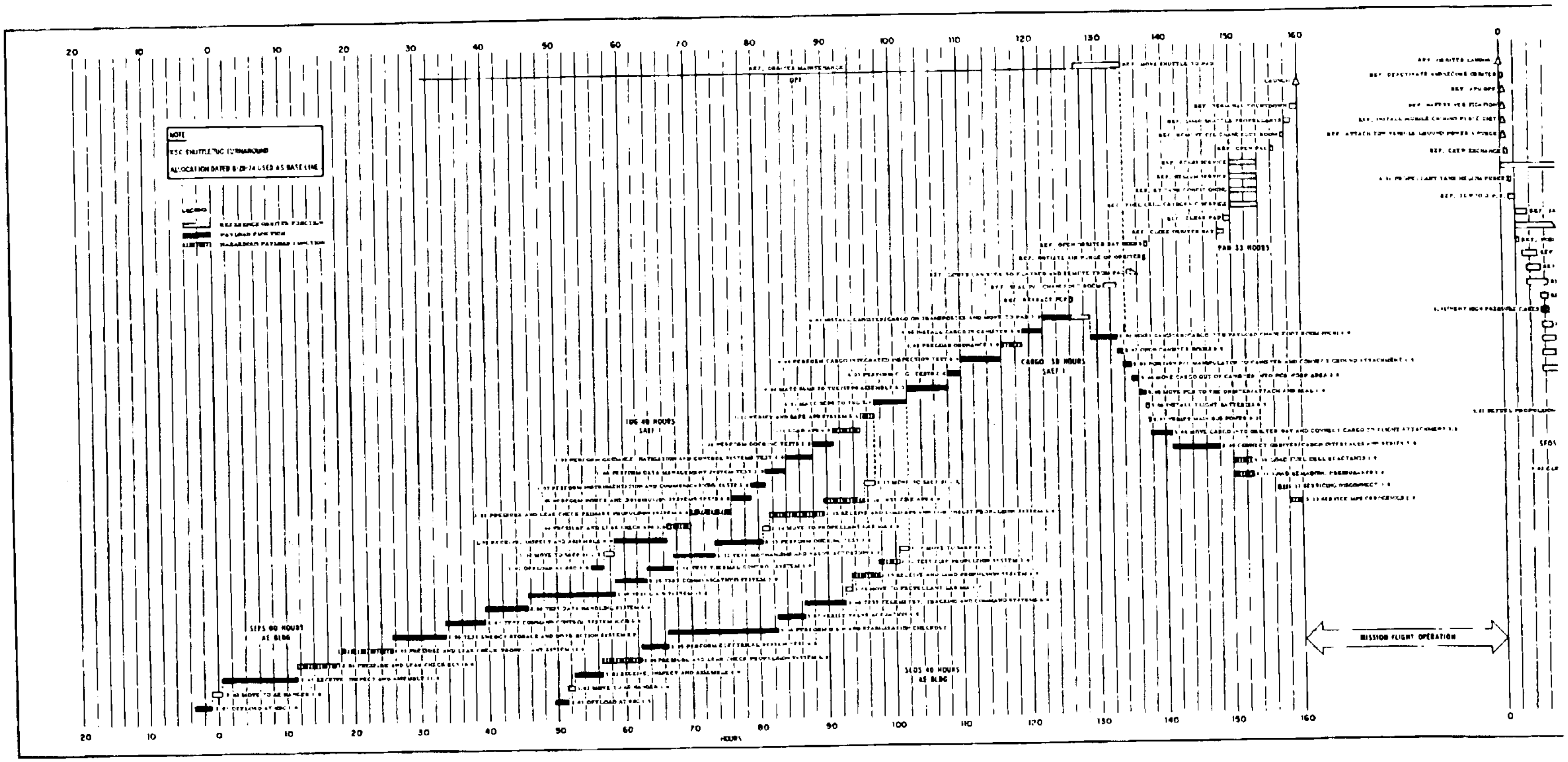

FIGURE 22. NORMAL BASE LINE PROCESSING FLOW TIME LINE FOR THE TUG/SEPS/SEOS CARGO

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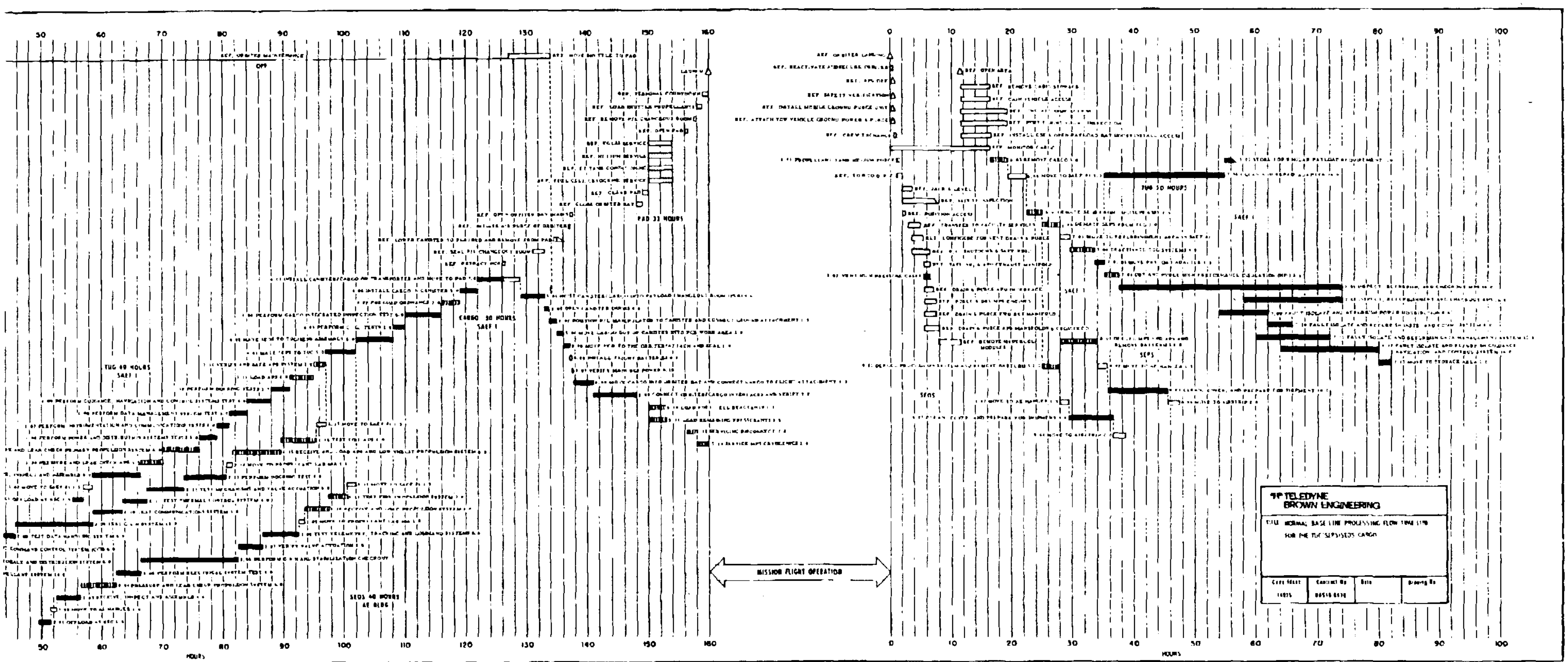

)W TIME LINE FOR THE TUG/SEPS/SEOS CARGO

The initiation of cargo post-flight operations are constrained by the 11 hr of Orbiter safing operations.

4.6 GSE AND FACILITY REQUIREMENTS

This section presents the major GSE and facility requirements for processing operations that have been identified as a result of the processing flows. These items are recognized as essential for the successful processing of the cargo.

Any experiment unique GSE will be furnished by the user, with the possible exception of transportation items or other items KSC may agree to furnish upon request. It was originally planned that specific experiment equipment would also be identified. However, there is insufficient information available to be definitive of particular experiments. Some facility requirements were envisaged to support different experiment groups, however.

For the Tug/SEPS/SEOS cargo,a support equipment listing of required equipment to meet specific processing requirements and functions was prepared. From this listing, support equipment identification sheets were prepared for servicing equipment and facility items that were new, peculiar, or associated with hazardous operations.

The Support Equipment Listings were separated into facility equipment, identified with a "F" number, and a powered cargo, identified with a "P" number. The "P" identification was further divided into servicing, handling and access, electrical, transportation, and miscellaneous by the addition of a appropriate second letter.

For the Tug/SEPS/SEOS cargo, 21 items of facility equipment and approximately 140 items of support equipment have been recognized as a result of the processing flows. From this listing, support equipment identification sheets were prepared for some items.The title, basic function, and description of these items are shown on these sheets. The support equipment listing for the following Tug/SEPS/SEOS equipment categories is included in Appendix D:

- Facility
- Electrical

- Handling and Access
- Servicing
- Transportation
- Miscellaneous.

4.7 PROCESSING HAZARDS SUMMARY

Twenty hazard types have been identified with 64 operational events in the Tug Cargo Normal Base Line Processing Flow. These hazard types, their HMEA number, the frequency with which they occur, and the final hazard categorization after the application of hazard reduction methods are as follows:

Hazard Types	HMEA Number	Frequency of Occurrence	Final Hazard Categorization
GN_2 Purge*	H002	15	Controlled
High Pressure GN_2*	H004	8	Catastrophic
High Pressure He*	H005	8	Catastrophic
Electrical Power*	H006	26	Controlled
RF Emissions	H007	4	Controlled
Hydrazine and Methyl Derivatives *	H008	6	Critical
Laser	H009	1	Controlled
High Temperature -- Elec. Heaters	H010	1	Controlled
Moving Equipment	H011	1	Controlled
Freon*	H012	1	Catastrophic
		2	Controlled
Mercury*	H013	2	Critical
APS Thruster Firing -- Toxic Gas	H014	2	Critical
Ordnance -- Safed *	H015	5	Controlled
Pyrotechnics --Armed*	H017	2	Controlled
Batteries *	H019	4	Controlled
Cryogenic LO_2*	H020	3	Critical
Cyrogenic LH_2*	H021	4	Critical
High Pressure --GN_2/ GHe*	H022	1	Catastrophic
		2	Controlled

* Also, continue or carry over to other operations and present the possibility of interface or interaction effects during subsequent operations.

Hazard Types	HMEA Number	Frequency of Occurrence	Final Hazard Categorization
Hydraulics	H023	1	Controlled
Purge With Hot GN_2	H039	1	Controlled

4.7.1 Hazard Mode and Effects Analysis

Functional Event Sheets for the Tug/SEPS/SEOS Normal Processing Base Line flagged each hazardous operation for a hazard analysis. By examining each operational event (where a hazard or hazards had been uncovered) in conjunction with the HMEA of that type of hazard (e.g., laser and electrical), a determination of the initial hazard impact on the payload, cargo, facilities, Orbiter, and personnel was made. The impact whether catastrophic, critical, or controlled and what was affected, such as payload and cargo, was indicated on the Normal Processing Base Line Flow along with the final categorization that shows the result after the application of control measures listed on the HMEA for that hazard type. The HMEA's for the 20 hazard types shown in Paragraph 4.7 are located in Appendix E.

4.7.2 Interface Hazards

If the hazard were a "one event only" hazard, it was indicated on the flow chart by a hexagon. If the hazard were one that would continue over several operational events, it was indicated by a circle and a line was run from the source event to the terminal event where the hazard was closed out with a hexagon. Events containing more than one hazard may have interface hazards associated with them, and also, events where hazards are contained from previous events operating on or operated on by an event initiated hazard can also have interface hazards. In this manner, the processing flow clearly shows all possible hazard interactions for each operation.

An interface hazard represents a potential accident type that could occur if one hazard source were to go out-of-control (an accident) and operate on another potential hazard source causing it to also go out-of-control. In accidents resulting from an interface, the combined effects are often a different and/or worse (synergistic) effect than the singular uncombined effects of either.

In the Tug/SEPS/SEOS Normal Base Line Processing Flow, 10 events present potential interface hazards. These hazards and their potential effects are described below:

- Tug Event 1.07 - Perform Instrumentation and Communications Systems Tests

- Tug Event 7.09 - Check Out Instrumentation and Communications Systems Tests

- SEPS Event 2.10 - Test Communication System

- SEOS Event 3.08 - Test Telemetry Tracking and Command Systems.

In each of these events, electrical power is applied to make checks and verifications of various communications and instrumentation networks. Either through human error or equipment malfunction, power could be inadvertently applied to the RF links, thereby producing RF emissions. The RF emissions can cause human injury and result in the malfunction of sensitive equipment within the range of the radiation field.

Similarily, electrical power application to make various other checks and verifications during normal processing operations could lead to additional interface hazards such as:

- SEPS Event 2.09 - Test G&N System.

Inadvertent power application to the laser radar during verification of the proper operation of the major G&N elements could lead to exposure of personnel and equipment to the laser beam, thereby resulting in possible personnel injury, fire, and/or equipment damage.

- SEPS Event 2.11 - Test Thermal Control System.

Electrical power application to the heaters to verify their operation in the Thermal Control System could result in an interface hazard. Should the heaters inadvertently not be shut down, or power accidentally applied to them after the test was complete, either through human error or heater malfunction, it is possible that an uncontrolled combustion could occur. This could result in the release of hot or toxic gases and possible personnel injury or fire and contamination.

- SEPS Event 2.12 - Test Mechanism and Valve Actuation

The application of electrical power is made to verify the command and control of the thruster gimbals in this event. Through a malfunction or human error, the inadvertent application of electrical power to the system at some other time could result in personnel injury and equipment damage.

- SEPS Event 2.16 - Test Fire APS
- SEOS Event 3.11 - Test Fire MPS

The thrusters are fired to check the operation of the propulsion systems. A thruster malfunction could result in the spillage of hydrazine, which in turn could be ignited by electrical power malfunction. This could result in a possible fire or explosion, leading to possible personnel injury and damage to equipment and facility.

- Cargo Event 5.09 - Connect Orbiter/Cargo Interfaces and Verify

In this event, electrical power is applied to verify the various Orbiter/cargo interfaces. Inadvertent power application to the pyrotechnic devices could result in an explosion or fire, which in turn could ignite the hydrazine released by the explosion, resulting in personnel injury and/or damage to the cargo and Orbiter.

4.8 SAFETY REQUIREMENTS AND LAUNCH SITE PROTECTION

Identification of the 20 types of hazards associated with the Tug Cargo Normal Base Line Processing Flow has presented the requirement for providing recommendations and/or preventative measures that could help to alleviate the severity/occurrence of the hazard. The detailed safety, operational, and facility requirements for each of these 20 hazards are presented in Appendix E. A summary of the more pertinent requirements that have been established for each of the identified hazards is presented below:

- GN_2 Purge (H002) and Hot GN_2 Purge (H039)

The prevention of personnel injury from asphyxiation can be effected most readily by limiting the access of personnel to areas where purge operations are being conducted, and to provide proper ventilation or self-contained breathing apparatus for those persons that must enter the area. Proper use of restraints or tiedowns and vent/relief capability can help preclude rupture of high pressure vessels and lines, and thereby prevent damage to personnel and equipment caused by whipping of unsecured lines, etc.

- High Pressure GN_2 (H004) and High Pressure He (H005)

High pressure testing or checking of tanks/lines/fittings always presents the hazard of a rupture or burst that could result in personnel injury and damage to facilities and equipment. Remote operation or, where required, provision for restricted access and appropriate caution and warning procedures can considerably reduce the exposure of personnel to such hazards.

- Electrical Power (H006)

Probably the single most effective means for preventing electrical shock to personnel is through the use of GFI devices. The use of proper operational procedures, checklists, and safety interlocks will help prevent the inadvertent creation of associated electrical hazards, such as arcing and high voltage discharge, which can result in fires and damage to equipment.

- RF Emissions (H007)

The wearing of RF monitors by operating personnel can effectively limit their exposure to such harmful radiation. All RF generating equipment should be turned off before performing hazardous operations, such as connecting pyrotechnics devices.

- Hydrazine and its Methyl Derivatives (H008)

The obvious requirements of wearing protective clothing, masks, and gloves and having safety showers and eye wash fountains readily accessible will in most cases preclude an accidental spill having a marked effect on personnel. Modifications to the SAEF #1 facility to include a water flush system and a fresh air purge may be required for loading and testing the APS safely.

- Laser (H009)

A laser checkout facility should be used to limit access to the area during testing, and to provide barriers and curtains to contain the reflected light. Eye shields should be worn at all times during tests with lasers.

- High Temperature Electric Heaters (H010)

Personnel should wear protective garments, gloves, etc., at all times when working with sources of high temperature. All combustible materials must be removed from the immediate area before the heaters are energized.

- Moving/Rotating Equipment (H011)

Provision must be made to limit access and clear the area before operating movable or extendable equipment and to ensure that there is no interference with the moving equipment during planned operations.

- Freon (H012)

Adequate facility ventilation and avoidance of smoking or open flames in the area where halocarbon vapors may be present should preclude most hazardous conditions to personnel from these materials.

- Mercury (H013)

Adequate ventilation and provision to rapidly clean up any spilled mercury should prevent most harmful effects of mercury vapor on operating personnel.

- APS Thruster Firing Toxic Gas (H014)

Test firing of these thrusters could generate toxic products such as ammonia and hydrogen, or through malfunction could create a spill of hydrazine. Adequate ventilation and the use of personal protective equipment should preclude any hazard to personnel from this operation.

- Pyrotechnics Safed (H015)

The inadvertent activation of ordnance devices can be precluded by the following proper procedures, such as using spark proof tools, use of shorting caps, and handling and storing explosions only in designated facilities.

- Pyrotechnics Armed (H017)

Before removing shorting caps from EED's and connecting pryotechnic devices, checks should be made for RF or magnetic fields and for energized electrical connectors.

- Batteries (H019)

Care must be exercised in handling batteries to prevent arcing/shorts and to prevent electrolytic spills. The use of nonsparking tools and wearing of protective clothing and goggles should serve to alleviate most of these hazards.

- Cryogenic LO_2 (H020)

Operations involving LO_2 significantly increase the fire hazard associated with combustible materials in the area. Working with cryogenics necessitates the wearing of personal protective gear, such as masks, and gloves to prevent personnel injury.

- Cryogenic LH_2 H021

Adequate ventilation during operations involving LH_2 can help prevent possible asphyxiation of personnel and the possibility of a fire or explosion. The cryogenic lines should be drained, purged, and warmed to ambient temperature before breaking connections to prevent spills, etc.

- High Pressure --GN_2/GHe (H022)

All operations involving the test, checkout, and operation of high pressure systems should be done remotely in as much as possible, i. e. limiting access and number of operating personnel. All GSE services should be vented and safed before disconnecting.

- Hydraulics (H023)

These systems should be treated for hazardous conditions just as other high pressure systems, with the added hazard that spills or leaks could lead to a possible fire hazard.

4.9 PAYLOAD SAFETY RELATED RECOMMENDED CRITERIA

Identification of the 20 types of hazards associated with the Tug Cargo Normal Base Line Processing Flow has also presented the requirement for providing pertinent payload design criteria that could help reduce the severity or occurrence of the hazard. The detailed criteria set forth for each of these hazards are provided in Appendix E. A brief summary of the more significant criteria emanating from this study is presented below:

- GN_2 Purge (H002) and Hot GN_2 Purge (H039)

No payload design requirements were found to be applicable to this hazard.

- High Pressure GN_2 (H004) and He (H005)

All high pressure tanks should be designed with pressure relief valves to limit pressure and the tanks should be designed to limit shrapnel in case of a inadvertent rupture or burst. Pressurized flight systems should be connected to the Orbiter vent system to allow venting before returning from orbit.

- Electrical Power (H006)

All electrical equipment, connectors, etc., should conform to the provisions of the National Electrical Code and the applicable NASA and MIL Standards. The designs of safety critical switches and controls should be such that they are readily accessible in the event of a major incident.

- RF Emissions (H007)

Equipment that generates EMI radiation should be designed to contain this radiation within the equipment and equipment that can be adversely affected by RFI should have RF shielding built into its design.

- Hydrazine and its Methyl Derivatives (H008)

The Orbiter/GSE umbilicals should be designed to limit spillage of fuels at the pad or other loading areas to a minimum.

- Laser (H009)

Safety related design features for laser operations should include electrical/mechanical interlocks to prevent inadvertent energization, limiters, or stops to limit pointing direction, and a control and warning system to provide a warning if the beam is out-of-limits.

- High Temperature Electric Heaters (H010)

Electrical/mechanical interlocks should be incorporated into the system to prevent inadvertent energization.

- Moving Equipment (H011)

All moving/rotating equipment should be provided with limit stops or shields to preclude contact with the equipment during operation.

- Freon (H012)

All systems using pressurized gases should include provisions for the relief of overpressure and for the venting of the systems in orbit.

- Mercury (H013)

Consideration should be given to designing mercury tanks and lines that are double sealed or contained to prevent leaks into the atmosphere or the Cargo Bay. The payload mercury tanks should not be brought up to operating pressure until the payload is deployed from the Orbiter in space.

- APS Thruster Firing --Toxic Gas (H014)

Design of the APS systems should include electrical interlocks to preclude inadvertent firing of the system, and provision should be made to bring the APS system up to operating pressure only just before deployment from the Orbiter in space.

- Pyrotechnics Safed (H015) and Armed (H017)

Ordnance firing circuits must be designed so that after one failure, a second failure will not fire the circuit. The payload design should include the location of the pyrotechnic initiators for easy accessibility when the cargo is in the Orbiter Bay.

- Batteries (H019)

Battery and battery connector designs should include the use of plug-in type connectors to cut down the possibility of arcing. The batteries should also have adequate vents that are connected to the Orbiter vent system that would preclude possible battery case over-pressure.

- Cryogenic LO_2 (H020)

Because of the shock sensitivity of a number of materials in LO_2, all seals and lubricants used must be compatible with LO_2. To avoid overpressurization, the fuel cell and LOX tanks should have redundant vent and relief valves that are connected to the Orbiter vent system.

- Cryogenic LH_2 (H021)

As for the LO_2 systems design, the fuel cell and LH_2 tanks should have redundant vent and relief valves that are connected to the Orbiter vent system. Where feasible, all such toxic/hazardous propellant systems should not be pressurized until just before deployment from the Orbiter in orbit.

- High Pressure GN_2/GHe (H022)

Design criteria applicable to GN_2 and GHe have been discussed previously under (H004) and (H005).

- Hydraulics (H023)

All payloads flown in the Shuttle should use non or low-flammable hydraulic fluids to reduce the hazards associated with these fluids.